RESPONSE OF WHEAT (*Triticum aestivum* L.) VARIETIES TO SOWING METHOD AND FERTILIZER TREATMENTS

BY

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DEPARTMENT OF AGRONOMY,
FACULTY OF AGRICULTURE,
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DECLARATION

I declare that this work in thesis entitled: **RESPONSE OF WHEAT (*Triticum aestivum* L.) VARIETIES TO SOWING METHOD AND FERTILIZER TREATMENTS**has been performed by me in the Department of Agronomy under the supervision of Professor A. A. Muhammad, Professor I. U. Abubakar and Dr. A. I. Sharifai. Information in the text derived from literatures has been duly acknowledged and list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other Institution.

____________________ ____________________

Alhaji Sherif WALI Date
(Candidate)

The above declaration is confirmed

____________________ ____________________

Professor A. A. Muhammad Date
Chairman, Supervisory Committee

CERTIFICATION

This thesis entitled: **"RESPONSE OF WHEAT (*Triticum aestivum* L.) VARIETIES TO SOWING METHOD AND FERTILIZER TREATMENTS"** by Alhaji Sherif WALI meets the regulations governing the award of the degree of Doctor of Philosophy of Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

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Professor A. A. Muhammad Date
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DEDICATION

This work is dedicated to the memories of my late parents: Sheikh Wali Ibrahim Umar and Hajja Zainawa Wali (ZB) (May Allah forgive them and make *Firdaus* their final abode, Ameen), to the entire *Waliri* family and to all victims of *Boko Haram* insurgency in the northeast especially my people from Bama for the incident of 1st September, 2014.

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ABSTRACT

Field experiments were conducted in 2014/2015 and 2015/2016 dry seasons at the Research Farm of the Institute for Agricultural Research, Samaru and Kadawa to study the response wheat varieties to sowing method and fertilizer treatment. The treatments consisted of three varieties (LACRIWHIT-1, LACRIWHIT-4 and LACRIWHIT-5), two sowing methods (broadcasting and drilling) and four fertilizer (zero fertilizer control, NPK at 120 kg N, 60 kg P_2O_5 and 60 kg K_2O ha^{-1}, Farmyard Manure at 10 t ha^{-1} and combination of NPK (60kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}) and FYM (5 t ha^{-1})). The treatments were laid out in a Randomized Complete Block Design and replicated three times. Growth attributes such as plant height, number of tillers, number of leaves and crop dry matter varied significantly among the varieties at different sampling periods and were generally found to be higher in LACRIWHIT-5 than LACRIWHIT-1 and 4. The variety LACRIWHIT-5 was superior to LACRIWHIT-1 and 4 in most yield attributes such as number of spike m^{-2}, spike length, weight of grain spike^{-1}, 1000-grain weight and total biomass at harvest. However, LACRIWHIT-1 and 4 headed, flowered and matured earlier. LACRIWHIT-1 had higher grain protein (12.28 and 12.59 %) and gluten content (9.73 and 9.66 %). Growth parameters such as stand count, number of tillers, number of leaves, leaf area, crop dry matter, CGR, RGR, NAR, days to maturity and effective tillers were significantly affected by sowing method with drill sowing giving higher values in most cases than broadcast. Drill sowing also significantly increased yield components such as number of spike m^{-2}, number of grains per spike, and grain weight as well as grain yield and grain moisture content. Fertilizer application significantly increased growth parameters such as plant height, number of tillers, number of leaves and crop dry matter, crop growth rate and hastened days to 50% heading, flowering and maturity. High stand count, taller plants and more tillers were obtained resulting from application of NPK alone or in combination with FYM than control treatment. Fertilizer application increased tiller production which directly influence leaf number and LAI of the crop.Days to 50 % heading, flowering and maturity was relatively earlier in the fertilized plots compared to the unfertilized ones. Yield components such as spike length, spike m^{-2}, 1000-grain weight, grain per spike and higher biomass yield of wheat were influenced by fertilizer application. From the study, highest yield was obtained with the application of NPK alone or in combination with FYM followed by FYM alone and the least was in the unfertilized control. Positive and significant correlation was observed between grain yield and most growth and yield components of wheat. These include plant height, number of tillers m^{-2}, LAI, crop dry matter, CGR, spike m^{-2}, spike length, spikelets spike^{-1}, number of grains spike^{-1}, weight of grains spike^{-1}, 1000 grain weight, total biomass and harvest index. Also, LAI significantly and positively correlated to CGR and RGR. The relationships between grain yield and days to 50% flowering, heading and maturity was negative. Similarly, correlation between number of grains spike^{-1} and 1000 grain weight was negative. In the path coefficient analysis, total biomass production had both the greatest direct effect and contributed more to grain yield followed by harvest index. The highest positive indirect contribution was from crop dry matter via weight of grain spike^{-1} as well as number of tillers m^{-2} via total biomass at Samaru and from weight of grain spike^{-1} via total biomass at Kadawa. The low residual values obtained in study suggest that the major characters contributing to the grain yield of wheat were measured. It was realized that only 1.2%, 38.70% and 34.37% at Samaru while at Kadawa 11.54%, 6.0% and 7.35% of the variability remain unaccounted in 2014/2015, 2015/2016 and their combined mean respectively. The partial economic analysis revealed that, at both locations application of combined NPK and FYM to drilled LACRIWHIT-5 resulted in the highest gross margin and profit per naira (₦) invested. The lowest gross margin came from broadcast LACRIWHIT-1 sown unfertilized followed by LACRIWHIT-5 under same treatment. Based on the findings of this study, it could be concluded that LACRIWHIT-5 was superior to LACRIWHIT-4 and LACRIWHIT-1 in most growth, yield attributes and yield while LACRIWHIT-1 produced more grain protein and gluten content than LACRIWHIT-4 and 5. Drill sowing was better than broadcast in terms of most growth, yield attributes and yield. Combined application of NPK (60kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}) and FYM (5 t ha^{-1}) or full dose of NPK (NPK at 120kg N, 60 kg P_2O_5 and 60 kg K_2O ha^{-1},) gave the highest grain yield. Therefore, drill sowing of variety LACRIWHIT-5 with application of either combined NPK (60kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}) and FYM (5 t ha^{-1}) or full rate of NPK (NPK at 120kg N, 60 kg P_2O_5 and 60 kg K_2O ha^{-1},) is suggested but economically, grain yield was best at the combination of NPK and FYM to drill sown LACRIWHIT-5.

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CHAPTER ONE

1.0 INTRODUCTION

Wheat (*Triticum aestivum* L.) belongs to the family Poaceae and ranks first in both area cultivated and production among cereal crops. It contributes more calories and proteins to the world's human diet than any other cereals. Globally, production is estimated at 749 million metric tonnes from about 220.4 million hectares (FAO, 2016). The highest average yields are obtained in Western Europe, with more than 8 t ha^{-1}, in contrast to about 1 t ha^{-1} in countries of Central and West Asia and West Africa (Rajaram and Braun, 2009). In Nigeria, it is a major crop as it is eaten as bread and other wheat-based products such as cakes, biscuits, macaroni, spaghetti, pasta, etc. (Falaki and Mohammed, 2011). Wheat possesses several health benefits (Heshe *et al*., 2016) against diseases such as constipation, ischaemic, heart disease, diverticulum, appendicitis, diabetes, and obesity especially when utilized as a whole-grain product (Kumar *et al*., 2011).

Wheat production in Nigeria is presently restricted (because of high temperature and humidity) to areas between latitudes 10-14^0 N (covering the Sudan and Sahel Savanna zones), during the cold harmattan period between the months of November and February, under irrigation (Olugbemi, 1994). Currently, Nigeria's production stands at 60,000 tonnes from about 51,000 hectares (Anon., 2016).

Cereal yield is generally low in soils of West Africa because of low soil phosphorus and nitrogen (Okpara and Igwe, 2014). Nigeria's Savanna soils are generally low in organic matter (Abdulkadir and Abu, 2013; Lawal and Girei, 2013), nitrogen and phosphorus (Adeosun, 2008; Lawan and Girei, 2013). Wheat in Nigeria is produced in the Savanna zone, and continuous cultivation which had replaced the traditional shifting cultivation causes soil nutrient and fertility depletion, structure degradation, reduced water infiltration, increased run off and erosion (Odunze, 2003; Lawal, 2012). Excessive use of chemical fertilizers causes soil and water pollution (Elhassan *et al*., 2010; Zhang *et al*., 2010; Lawal and Girei 2013).

In recent times, attention has been directed towards organic fertilizers owing to hazardous environmental consequences and high cost of inorganic fertilizers (Jilani *et al*., 2007; Chaudhry *et al*., 2009; Shiyam and Binang, 2011 Oyedeji *et al*., 2014). Integrated plant nutrient management enhances soil productivity and sustains crop production (Dilshad *et al*., 2010; Aslam *et al*., 2011a). Farmyard manure (FYM) significantly influenced the soil organic matter concentration (%) in soil as compared to application of recommended NPK (Aslam *et al*., 2011b; Abbas and Fadul 2013). Generally, combined application of organic manure and chemical fertilizer improves soil fertility, soil physical and chemical properties and increases crop yields (Ezekiel, 2010; Liu *et al*., 2010).

FYM is one of the organic fertilizers used by Nigeria's peasant farmers. Benefits of FYM and in combination with inorganic fertilizer have been reported in wheat (Ali *et al*. 2011; Jibrin and Fagam, 2012; Khan *et al*., 2013a, Zahoor, 2014) and other crops such as maize (Shah *et al*., 2009; Achieng *et al*., 2013, Adesoji., 2013; Zehirun *et al*., 2013), millet (Sadiq *et al*., 2012; Bakhashwain *et al*., 2013) sorghum (Ahmad *et al*., 2007) soybean (Bhattacharyya *et al*., 2008) etc.

Traditionally wheat is planted using broadcast method (Abbass *et al*., 2009) and recently there is a shift from the broadcast to drilling (Soomro *et al*., 2009; Amin *et al*., 2013a; Naresh *et al*., 2014). However, there are still conflicting results on the various methods owing to relative advantages and ultimate yield as broadcasting is easy to do, while drilling is easy to weed. Carver (2005) investigated the impact of different crop establishment methods in winter wheat. Broadcasting method produced the most effective spatial arrangements. However, there was no consistent relationship between any of the spatial arrangement and subsequent yield performance. Singh *et al*. (2005) reported in India, that in wheat, strip drilling resulted in higher growth and grain yield than the broadcasting. However, Ahuja *et al*. (1996) recorded highergrain yield in broadcasting compared to drilling. In a recent study in india Abbass *et al*. (2009) also reported higher yield in broadcast than drilling at 15, 22.5 and 30 cm spaced rows. More recent studies indicated higher yield in drill method over broadcasting (Amin *et al*., 2013a; Naresh *et al*., 2014)

Performance of different varieties of wheat under different management and environmental condition is of interest to the agronomist. Over the years, several wheat varieties have been developed and released in Nigeria (Miko, 2012). These varieties vary in their response to management and environmental condition. Significant differences in grain yield among wheat varieties were reported in various wheat growing areas of Nigeria; Bauchi (Jibrin and Fagam, 2012), Borno (Bibinu *et al*., 2016), Kano (Falaki and Mohammed 2011) and Sokoto (Sokoto and Singh, 2013). Similarly, variation in yield and yield components of wheat varieties under organic (Jibrin and Fagam, 2012; Abbas and Fadul 2013), inorganic (Asargew *et al*. 2014;Farrokh and Farrokh 2014) and their combinations (Akhtar *et al.,* 2011*;* Zahoor, 2014) were also reported in Asia and other parts of the globe.

54.2. **Justification and Objectives**

The importance of wheat in the global and Nigerian context cannot be overemphasized considering the hectareage cultivated and the various uses of the crop (FAO, 2010; Falaki and Mohammed, 2011). Despite the huge land put under wheat production, the demand for wheat is yet to be met. With human population expected to reach 8.3 billion globally by 2025, coupled with continuous deterioration and losses of agricultural lands

(Mannion, 1998), it has become imperative to develop ways to harness the limited resource for maximum production to feed human population.

Local wheat production is grossly inadequate (Falaki and Mohammed, 2011; Olabanji *et al*., 2012) thus Nigeria annually imports over $3 Billion worth of wheat (Anon., 2016). Local production is hampered with challenges (Olabanji *et al*. 2012). One of such challenges is low soil fertility (Adeosun, 2008; Law-Ogbomo *et al*., 2012; Okpara and Igwe, 2014) hence the use of inorganic fertilizer. However, excessive use of chemical fertilizer is associated with health hazards (Elhassan *et al*., 2010; Nyangani, 2010; Zhang *et al*., 2010) and high cost. Therefore, it is considered not only too costly but also out of reach of the poor farmers (Shiyam and Binang, 2011; Lawan and Giere, 2013). Integrated plant nutrient management is a method of combining chemical fertilizers with organic manures (Jilani *et al*., 2007; Chaudhry *et al*., 2009) and is found to enhance soil productivity and sustains crop production (Dilshad *et al*., 2010; Nyangani, 2010; Aslam *et al*.2011b). The use of Farmyard manure (FYM) in this system significantly influences organic matter concentration (%) in soil as compared to application of recommended NPK alone (Abbas and Fadul, 2013). However, famers rarely practice use of FYM in wheat production in Nigeria.

Wheat sowing using broadcasting dominated the traditional production system (Amin *et al*., 2013b). The present trend is a shift toward drilling method (Khan *et al*., 1990; Singh *et al*., 2005). There are reports of higher yield under broadcast compared to drilling (Carver, 2005; Abbas *et al*., 2009). However, the degree of response to management and environment differ with variety (Orakwue *et al.*, 1991; Miko *et al.*, 2006; Bibinu and Gwadi, 2014). Several wheat varieties have released by LCRI. These varieties vary in their yield potentials hence the need to evaluate for their response to management conditions, particularly fertilizer and sowing method. This is important where soil fertility is low and appropriate sowing enhances crop establishment and easy management. There is paucity of information on the use of FYM in wheat production in Nigeria and application of integrated plant nutrient management system under different sowing methods for wheat production. The pertinent questions are: can integrated plant nutrient management system enhance their performance? Can the sowing methods affect their performance? How significant will be the response of the varieties under such condition? These considerations prompted the need to carry out this study with the following objectives.

1. To assess the growth, yield components and yield and of wheat varieties.
2. To determine the appropriate sowing method for wheat production.
3. To determine the effect of FYM, NPK fertilizer and their combination on growth, yield components and yield of wheat.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Growth Variability of Wheat Varieties

Previous studies have indicated significant difference in the behaviour of wheat varieties. The differences in yields among cultivars, and between seasons are commonly associated with differences in growth and yield attributes and to genetic differences (Awan *et al*., 2012; Anwar *et al.*, 2011; Mushtaq *et al*., 2011). Falaki and Mohammed 2011) attributed differences in wheat growth and yield components to variable environmental conditions and genetic variability of the tested genotypes. Also, Miko *et al*, (2006) found differential response of wheat varieties to the growing conditions, which was attributed to their varied reactions to applied fertilizers and adaptability to environment.

Saleem *et al.* (2007) in their work at Peshawar, Pakistan, reported non-significant difference among varieties on days to emergence. However, maximum days to emergence (9.55) were recorded for varieties Ghaznavi, Fakhre-Sarhad and Bakhtawar-92 while minimum (9.50) were taken by Tatara-96. The possible reason for maximum days to emergence by these varieties could be variation in the soil. Bibinu and Gwadi (2014) in a study at Kirenowa showed significant differences in plant establishment among entries and having better establishment than the local check (Seri-M82).

Falaki *et al*. (2009) observed that height of the wheat varieties differed significantly. Linfen, Gen/Rabe and Trigo produced significantly taller plants compared with Seri/Buc/weaver/Pfau while the other varieties had statistically similar and intermediate values except variety Seri/Buc/weaver/Pfau. Simlarlly, Saleem *et al.* (2007), Falaki *et al.* (2009), Falaki and Mohammed (2011) and Awan *et al*. (2012) observed variable plant height in different varieties and attributed the differences in plant height to variable environmental conditions and genetic variability of the tested genotypes as was earlier reported by Anwar *et al.* (2011); Mushtaq *et al.* (2011). Mani *et al.* (2012) observed that check variety (Atilla Gan Atilla) was taller, took longer days to heading and yielded more than the introduced varieties.

Hiltbrunner and Liedgens (2008) established nine different winter wheat varieties and found the best yielding varieties with the most intense tillering and attributed the differences in number of tillers among varieties to their genetic diversity. Falaki *et al*. (2009) in a study conducted at Chiyako in Jigawa State evaluated the performance of thirteen improved heat tolerant wheat varieties and observed that all the varieties produced statistically similar number of tillers per plant except Seri/Buc/weaver/Pfau. Similarlly, Awan *et al*. (2012) Falaki and Mohammed (2011) observed variation in number of tillers/plant among varieties.

Bhatta *et al*. (2017) observed significant effect of genotype on LAI of wheat at various growth stages and locations. They attributed these differences in LAI for genotypes to different canopy characteristics of the genotypes under study. Similarly, Laghari et al. (2010) in their study at Pakistan comparing three wheat varieties (TD-1, T.J-83and Mehran-89) observed that variety TD-1 had significantly higher leaf area index than T.J-83and Mehran-89 and ascribed the difference to genetic constituents of the varieties.

2.2 Yield and Yield Components of Wheat of Variety

Falaki *et al*. (2009) using thirteen wheat varieties observed that number of spikelets spike^{-1} of Linfen was significantly higher but statistically similar with the other varieties except Molcep and Seri/Buc/weaver/Star which had the least value. Also, Saleem *et al.* (2007) and Falaki and Mohammed (2011) observed differences in number of spikelets spike^{-1} among varieties. Awan *et al*. (2012) found non-significant differences among wheat varieties for spike length. However, variety Chakwal-50 had longer spike of

10.9cm as compared to Local Damani showing spike length of 9.1 cm. Falaki and Mohammed (2011) observed that variety Silver-15 and Tody-6 had the longest spikes while Betriq-4 produced the shortest spikes. Also, Falaki *et al*. (2009) reported significant variation in spike length with Ster//TR having the longest spike while the shortest spikes were produced by Molcep. However, they observed the other varieties to have virtually similar and intermediate spike lengths.

Saleem *et al.* (2007) observed significant variation among varieties on days to heading with variety Fakhre Sarhad recording the longest number of days (127.05) followed by Ghaznavi (126.60), Tatara-96 (126.25) and Bakhtawar-96 (125.50) respectively. Bibinu and Gwadi (2014) and Awan *et al*. (2012) also observed significant variations in days to heading of wheat.

Bibinu and Gwadi (2014) revealed that the 19 genotypes produced higher number of seeds per spike, heavier thousand grain weight than the local check. Falaki *et al*. (2009) Falaki and Mohammed (2011) observed the number of grains/spike of the wheat varieties differed significantly, with variety Mexicali-75 and Tody-6 having statistically similar and higher grain weight/spike compared to varieties Minimus- 2, Silver-15, Nasser-5 and Anser-8, which have intermediate number of grains spike^{-1}. Falaki *et al*. (2009) reported variety HD2206 had statistically higher but similar grain weight spike^{-1} with CNDO, Gen/Rabe and Ster//TR, compared with the other varieties while Seri/Buc/weaver/Pfau had the least values. Miko *et al*. (1999) also observed significant difference in number of spike m^{-2}, grain weight and yield of wheat varieties at Kadawa in which Siete Ceros outperformed Pavon 76.

Thousand-grain weight is a major contributor to the final grain yield. Awan *et al*. (2012) observed that Chakwal-50 and Zam-04 produced the highest 1000 grain weight of 44.6 and 43.8 g, respectively than others evaluated. They concluded that the significant differences might be due to inherent genetic potential and existing climatic condition especially during seed filling stage, which may play a very decisive role for a variety to attain heavier or light mass. Similarly, Bibinu and Gwadi (2014), Falaki and Mohammed (2011) and Falaki *et al.* (2009) reported significant difference on 1000-grain weight of wheat varieties.

Sokoto and Singh (2013) in a two year trial conducted at the Fadama Teaching and Research Farm, Usmanu Danfodiyo University, Sokoto within the Sudan Savanna reported that there was a significant effect of variety on grain yield in both seasons and combined, Star II TR 77173 differed from Kauz/Weaver with higher grain yield and attributed it to better LAI, NAR, CGR and yield component exhibit. Falaki *et al*. (2009) observed that variety CNDO and Ster//TR had significantly higher grain yield compared to Seri/Buc/weaver/Pfau while the other varieties had statistically similar and intermediate grain yields. Differences in grain yield due to variety have also been reported by Awan *et al*. (2012). They observed that varieties3Hashim-8 and GA-2002 produced significantly the highest grain yield (3440 and 3767 kg ha^{-1}) while the lowest and statistically similar grain yield (1767 and 1400 kg ha^{-1}) was recorded for Fareed-06 and Local Thal, respectively. The higher grain yield in Hashim-8 and GA-2002 was probably due to higher number of tillers per unit area recorded in these two varieties. Usman *et al.* (2006) tested nine wheat lines and found a positive correlation of fertile tillers and the grain yield. Local landraces usually do not have a wider adaptability and they perform better in locality where they are acclimatized for decades.

2.3 Effects of Sowing Methods on Growth of Wheat

Wheat is usually sown by either drilling closely spaced rows 10-30 cm apart on the flat or by broadcasting the seed on a levelled soil surface and then incorporating it by means of a shallow tillage operation (Sayre and Ramos, 1997). Wheat sowing methods are placement of seeds in the soil at predetermined depth in line with drill machine (drilling) and dropping of seed on surface of soil (broadcasting) (Amin *et al.*, 2013a). Researchers have reported varying effects of sowing methods on the growth and yield parameters of wheat (Abbas *et al*., 2009; Nasrullah *et al*., 2010; Sulieman, 2010; Amin *et al*., 2013a; Naresh *et al*., 2014). Several sowing methods are adopted for wheat (Ashrafi *et al*., 2009; Soomro *et al*., 2009; Alam, 2012; Ali *et al*., 2012; Amin *et al*., 2013a & b). In Nigeria, the most common sowing methods for wheat are broadcasting and drilling at various distances (LCRI, 2009). Broadcasting is defined as sowing or sowing seeds cross an area by scattering either by mechanical means or by hand. While drilling involves dropping seeds continuously in rows in a definite depth, covered with soil and compacted. Broadcasting is considered the most economical method of applying seed to large areas of land (USDA, 2009). The broadcast is termed traditional or conventional because of its long practice. Sowing methods play a significant role in enhancing the wheat establishment Amin *et al*. (2013a) and yield (Shah *et al*., 2013). Traditional sowing method is the predominant method adopted by the farmers in wheat growing areas of Nigeria. There has been growing controversies on the appropriateness of sowing method among researchers. Some are of the view that broadcasting is cheap and time saving and gives more Sulieman, (2010) or similar Abbas *et al*. (2009) grain yield compared to drilling method. Others opined that conventional sowing method is one of the reasons for low crop productivity in wheat (Ali *et al*., 2012).

Sowing method had significant effect on emergence of wheat. Amin *et al*. (2013b) in a study at Peshawar, Pakistan observed maximum emergence under seed drill, while minimum emergence was recorded when broadcast method of sowing was used. Similar effect was reported by (Singh *et al*., 2007; Naresh *et al*., 2014; Ali *et al*., 2012). Delayed germination and emergence can ultimately reduce tillering and delay maturity such that grain filling occurs under higher and less productive temperatures (Ali *et al*., 2012). It is the combination of poorer stands and delayed emergence that puts broadcast seeding at risk of lowering yields (Ali *et al*., 2012). However, Abbas *et al*. (2009) from two year field experiments in sandy loam soils of arid area of southern Punjab, Pakistan revealed that drill-sowing technique of wheat was inferior to broadcast method.

Researchers have reported that sowing methods imparted significance difference in plant height (Amin *et al*. 2013b). Abbas *et al*. (2009) reported that better plant height was noted in drill sowing with 30 and 25cm rows, similarly, Khan *et al*. (2007), Soomro *et al*. (2009), Abbas *et al*. (2009), Nasrullah *et al*. (2010), Safdar *et al*. (2011), Ali *et al*. (2012) and Naresh *et al*. 2014) reported taller plants in drill sown wheat than broadcasted. However, Ansari *et al*. (2006) reported that maximum plant height was recorded with broadcasting method. Similarly, Ashrafi *et al*. 2009 in studies at Iran comparing Line, Line + Broadcast and Broadcast Sowing methods found plant height were statistically at par with each other, but surpassed the Line Sowing. More plant height (102 cm each) was recorded in Line + Broadcast and Broadcast Sowings.

Sowing methods had significant effect on number of tillers m^{-2}. Naresh *et al*. (2014) comparing broadcast and drill sowing at spacing of (15, 17.5, 20, 22.5 and 15:25 cm) observed significantly higher tillering in the drill treatments over broadcasting method and drilling at 22.5 cm apart. Similarly, Khan *et al*. (2007) and Soomro *et al*. (2009) reported that number of tillers $plant^{-1}$ were higher in drill sown wheat than broadcast. However, Abbas *et al*. 2009 comparing sowing methods did not observe difference between broadcast and drill sowing at spacing of (15, 22.5 and 30) cm influencing tillering in wheat during both the years. Similarly, Nasrullah *et al*. (2010) in a study at Bahawalpur, Pakistan reported significant difference in number of fertile tillers m^{-2} of wheat. They observed averaged maximum number of tillers m^{-2} (377.0 and 378.3) in broadcast than the drill methods.

2.4 Effects of Sowing Methods on Yield and Yield Components of Wheat

Sowing methods have significant effect on the yield and yield components of wheat. Naresh *et al*. (2014) reported maximum number of spikelets $spike^{-1}$ in 15:25 cm paired drill method of seed placement, although it was statistically at par and closely followed by the 20 cm apart drill. More number of spikelets $spike^{-1}$ in 20 cm and 15:25 cm drill sowing can be referred to the ideal plant population in the both treatments which resulted in less crop plant competition. Ali *et al.* (2012) in an experiment at Pakistan observed maximum number of spikelets $spike^{-1}$ was recorded in bed sowing method which was statistically at par with ridge sowing method. Minimum number of spikelets $spike^{-1}$ was recorded with broadcasting. Similarly, Khan *et al*. (2007), Singh *et al*. (2007), Soomro *et al*. (2009) and Amin *et al*. (2013b) reported that number of spikelet $spike^{-1}$ was higher in drill sown wheat than broadcasted. However, Abbas *et al*. (2009) observed number of spikelet $spike^{-1}$ was statistically similar in broadcasting and drilling at 22.5 cm apart rows.

The number of spikes per unit area is the most important trait contributing to the grain yield in wheat. Nasrullah *et al*. (2010) observed almost similar spikes m^{-2} in all methods of sowing. However, line sowing produced the highest spikes m^{-2} (276.47) compared to Line + Broadcast (269.53) or Broadcast (246.73) sowing. Similar result was observed by Ashrafi *et al*. (2009). Change in number of grains per spike drastically influences the final yield. Ashrafi *et al*. (2009) observed significant difference in grain per spike, highest grain per spike (53.213) in line sowing. Similarly, Ali *et al*. (2012), Soomro *et al*. (2009) and Khan *et al*. (2007) reported that number of grains/spike is higher in drill sown wheat than broadcast. However, it was statistically at par with line + broadcast sowing (50.197) but higher than broadcast sowing (44.2). Khan *et al*. (2007) and Abbas *et al*. (2009) observed that number of grains/spike was not significantly affected by different sowing methods. Nasrullah *et al*. (2010) in a two year study reported significantly maximum number of grains per spike of 42 and 44 in 2007-08 and 2008-09, respectively for T1, T2. The lowest number of grains 39 and 39.33 per spike were found in case of T3 (Rabi drill sowing in dry condition and followed by irrigation) during both the years of study respectively. The higher number of grains was due to longer spike, resulted from efficient use of crop inputs. Naresh *et al*. (2014) reported that, drill sowing at 20 cm produced statistically similar number of grains per spike during individual years (53.0, 55.5, and 52.6) and average over the years (53.7). The lowest numbers (42.7, 43.8, 44.2, and 43.6, respectively) were produced when sowing was done in 15 cm spaced rows during the individual year and average of the years as well.

Khan *et al*. (2007) observed higher thousand grain weight was in line sown 30cm apart (39.85g) followed by cross sown (37.30 g), while lower thousand grain was recorded for broadcast sowing method (32.09 g). Tanveer *et al*. (2003) also reported smaller 1000-grains weight for broadcast sown wheat as compared to wheat sown with other sowing methods. Ali *et al*. (2012) Abbas *et al*. (2009) Soomro *et al*. (2009) and Khan *et al*. (2007) also reported that 1000- grain weight higher in drill sown wheat than broadcasted.

Nasrullah *et al*. (2010) in a study at Pakistan observed significant differences among 1000-grains weight, maximum grain weight (41.5 g) was obtained in case of T5 (broadcast of seed in dry condition and augmented with furrows followed by irrigation) while the lowest (39.34 g) was in case of T4 (Seed spreading in standing water "Gup Chutt"). Ashrafi *et al*. (2009) reported maximum1000 grain weight (39 g) in line +

broadcast sowing, but it was significantly higher than the line and broadcast sowing (37 g). Naresh *et al*. (2014) in a three years study at Muzaffarnagar district of western Uttar Pradesh, India recorded the maximum 1000 grain weight of 42.8 and 43.1 g of 15:25 cm paired row spacing method.

Ali *et al*. (2012) Soomro *et al*. (2009) Khan *et al*. (2007) and Singh *et al*. (2005) reported that grain yield were higher in drill sown wheat than broadcasted.Similar findings were also reported by Naresh *et al*. (2014) Bruns (2011), Steckel and Gwathmey (2009), Wrather *et al*. (2008) and Khan *et al*. (2007). Contrary results were reported by Abbas *et al*. (2009) who observed maximum grain yield through broadcast method. They concluded that broadcast method is suitable for wheat sowing in sandy loam soils. Similarly, Carver (2005) and Singh *et al*. (2005) are in contradictory to the present findings. It might be due to varying environmental and soil conditions.

Ashrafi *et al*. (2009) showed that almost similar grain yield was recorded in all methods of sowing. However, the line + broadcast had a slightly higher yield (4142.78 kg ha^{-1}) as compared to line (4078.39) or broadcast sowing (4088.53). Naresh *et al*. (2014) revealed that, during 2008 to 2009, the maximum grain yield of 4491 kg ha^{-1} was produced when wheat was sown at T6 15:25 cm paired rows. The maximum grain yield producing treatment, however, was at par with T3 17.5 cm and T4 20 cm apart rows sowing method of sowing with a grain yield of 4316 and 4463 kg ha^{-1}. Sowing at T2 15 cm apart rows and T1 broad-casting method produced grain yield of 3970 and 4083 kg ha^{-1}, which were statistically lower than the above-mentioned treatments, although at par with one another.

Amin *et al*. (2013a) observed effect of sowing method on harvest index of wheat, maximum harvest index (46.2 %) was obtained from SD sowing methods followed by CD with (44.1 %) while minimum harvest index (43.6 %) was obtained by (BC) broadcast method of sowing. Similar observation was made by Singh *et al*. (2007) who reported that drilling produced higher values of growth, yield attributing characters, grain and straw yield than conventional sowing method.

Biological yield is the major contributor to the total output of any crop and depend upon species, growing season and other factors. Ashrafi *et al.* (2009) observed significant difference in sowing method on biological yield. Highest biological yield (17763 kg ha^{-1}) was recorded in Line sowing, while Line +Broadcast (16739) and Broadcast sowing (15970). Amin *et al*. (2013a) reported that average values for biological yield due to different sowing methods ranged from 9560 to 10320 kg/ha. A maximum biological yield of 10320 kg ha^{-1} was recorded when combined drill was used followed by SD with 10146 kg ha^{-1}, while minimum 9560 kg $ha^{-1}$was obtained when broadcast method of sowing was used. Singh *et al*., (2007) reported that sowing by drill produced higher yield attributing characters, grain and straw yield followed by conventional sowing. Naresh *et al*. (2014) reported highest straw yield (4698 kg ha^{-1}) from 15:25 cm paired rows sowing method and the lowest straw yield (3920 kg ha^{-1}) from 15 cm row spaced sowing method. Similar observation was made by Rahman *et al*. (2010).

2.5 Effect of Fertilizer on Growth and Development of Wheat

Optimum growth and production of a crop is mainly determined by variety, management, and environment (Abbas *et al*., 2013). Several soil management practices like tillage, mulching, fertilizer application and manuring are carried out to improve soil conditions for crop production (Aslam *et al*., 2011a). Increase in production can only be achieved with a proper combination of agronomic practices, proper use of inputs, cultivation of high yielding varieties and plant protection measures under the specific climatic conditions. Cropping system adopted in the irrigated sector do not allow for the build up of high level of organic matter since all crop residues are either removed or burned (Adamu *et al*., 2012; Abbas *et al*., 2013). Although, the use of mineral fertilizers cannot be overlooked; however, due to their rising costs (Elhassan *et al*., 2010) and environmental and health concerns, there is a need to supplement or substitute them with available organic resources (Jilani *et al*., 2007; Chaudhry *et al*., 2009; Aslam *et al*. 2011a). Therefore, integrated nutrient management including application of organic manures and biofertilizers is practiced to enhance soil fertility and sustain crop production (Hussain *et al*., 1999). Application of different organic manures to wheat crop might give a substitute under field conditions (Adamu *et al*., 2012).

Farmyard manure (FYM) significantly influenced the organic matter concentration (%) in soil as compared to application of recommended NPK (Abbas and Fadul, 2013). Generally, combined application of organic manure and chemical fertilizer improves soil fertility, soil physical and chemical properties and increases crop yields (Ezekiel, 2010). Aslam *et al*. (2011a) reported that one time application of FYM (10 -15 t ha^{-1}) increased wheat yields for up to three successive crop cycles when applied in conjunction with inorganic N fertilizers. Organic matter affects crops growth and yield either directly by supplying nutrients or indirectly by modifying soil physical properties such as stability of aggregates, porosity and available water capacity that can improve the root environment and stimulate plant growth (Rasoulzadeh and Yaghoubi, 2010). Soil organic matter affects infiltration through its positive effect on the development of stable soil aggregates, or crumbs. Highly aggregated soil has increased pore space and infiltration. Soils high in organic matter also provide good habitat for soil biota, such as earthworms, that through their burrowing activities, increase pore space and create continuous pores linking surface to subsurface soil layers (Anonymous. 2008). Organic matters not only increase the water holding capacity of the soil but also the portion of water available for plant growth and improve physical properties of soil (Sial *et al*., 2007).

Fertilization with organic and inorganic fertilizers and their combinations greatly influenced growth and yield parameters of wheat. Rehman *et al*. (2008) in their study at Pakistan observed that, combinations of NPK significantly increased emergence per m^2 as compared to control plots. With the increase in NPK combinations, emergence per m^2 increased significantly and reached to the maximum (83.5) at the highest level of 80-60-60 kg NPK ha^{-1} while minimum emergence per m^2 (79.3) was recorded from control plots. Linear increase in emergence per m^2 was observed with the increase in NPK combinations however, no significant difference was recorded between 80-60-60 kg NPK ha^{-1} and 80-60-30 kg NPK ha^{-1}. Individual effect of N, P and K, showed that emergence per m^2 increased linearly with the increase in N, P and K levels. Abbas *et al*. (2012) observed significant effect of FYM, NPK and their combinations on number of plants per m^2, 6 t poultry manure + recommended NPK produced the highest number while the control has the least. This was followed by 10 t FYM and recommended NPK respectively. Akhtar *et al*. (2011) in a study conducted at Faisalabad, Pakistan during 2006-07 and 2007-08 comparing the integrated use of organic manures [farmyard manure (FYM) and sesbania (*Sesbania rostrata*) as green manure] and inorganic fertilizer on wheat yield reported no significant differences among treatment regarding number of plants per square meter at emergence during both the years.

Plant height is an important growth character directly linked with the productive potential of plants in terms of fodder and grain yield. Shah *et al*. (2010) reported significant increase in plant height in FYM and FYM + mineral fertilizer treatment ($P < 0.05$) over control, they attributed the maximum height in FYM plus mineral N combine treatment to the fulfilment of the N requirements at early growth stages by the mineral N while farmyard manure facilitated crop with maximum nutrients in later stages. Thus excellent vegetative growth and development resulted in maximum plant height. Similarly, Iqbal *et al.* (2002), Abbas and Fadul (2013) observed that application of mineral N alone or with organic N increased plant height significantly due to the stronger role of N in cell division; cell expansion and enlargement which ultimately affect the vegetative growth of wheat plant particularly plant height. Abbas *et al*. (2012),Hammad *et al*. (2011), Rehman *et al*. (2010), El-Ghamri *et al.* (2009) Channabasanagowda *et al.* (2008) and Sharma *et al.*, (2005) reported significant effects of organic and inorganic fertilizers and their combinations on plant height of wheat. The favourable effects of FYM and NPK on plant height of wheat may be attributed to more availability of macro and micro nutrients and improvement in soil water holding capacity (Matsi *et al*., 2003; Hossain *et al*., 2002). However, Ali *et al*. (2011) in their experiment in 2008-2010 observed that FYM in combination with different doses of phosphatic fertilizer did not significantly influence plant height among the treatments.

Fertilizer application to wheat particularly N during early stages of development greatly increased leaf area by delaying leaf senescence, sustained leaf photosynthesis and extended leaf area duration which ultimately resulted in maximum Leaf Area Index (LAI) compared with control (Zhang *et al*., 1998). Rehman *et al*., (2010) working on FYM and NPK on wheat reported that leaf area index significantly increased with the application of NPK and maximum (2.50) was recorded at the highest level of NPK 80-60-30 kg ha^{-1} compared to the control (2.19). FYM showed no significant increase in leaf area index however, maximum leaf area index (2.46) was recorded at highest level of 45t ha^{-1} FYM while minimum harvest index (2.30) was recorded in the control.

Numberofproductive tillers per m^2 is one of the important yield determining parameters of wheat. Akhtar *et al*., 2011) reported significant differences among the means of different treatments on number of spike bearing tillers, sesbania as green manure + 150-100-50 kg NPK (474) and FYM + 150-100-50 kg NPK (473) produced the maximum number of spike bearing tillers . However, these treatments were statistically at par with 150-100-50 kg NPK (468) and 75-50-25 kg NPK (467) treatments. Minimum spike bearing tillers (447) were found in control and (448) where only green manuring was done. Similarly, (Rehman *et al*., 2010) found linear increase with the increase in NPK levels and maximum tillers per m^2 (330) were noted at 80-60-60 kg NPK ha^{-1} while minimum tillers per m^2 (290) in the control. Application of FYM to the soil may have increased tillers per m^2 due to improved soil fertility, increased soil organic matter, enhanced microbial activities and improved soil structure (Blair *et al*., 2006, Kundu *et al*., 2007). Hammad *et al*. (2011) did not observe significant difference on number of productive tillers per unit area when different organic manures were used, however maximum productive tillers (274.8) were recorded where NPK at the rate of 160+100+50 kg ha^{-1} was applied and minimum (192.0) was observed in control. The addition of FYM increased P mobilization and soil microbial activities (Jan and Noor 2007 and Akhtar *et al*., 2011).

2.6 Effect of Fertilizer on Yield Components and Yield of Wheat

Zahoor (2014) in an experiment at observed that application of 10 tons FYM ha^{-1} before sowing increased the number spike per m^2. Rehman *et al*. (2008) reported significant increase in number of Spikes per m^2 by FYM and NPK over the control. Spike length is another important yield component, which affect the number of grains per spike. Shah *et al*. (2010) reported both organic and inorganic N sources had significant effect ($P< 0.05$) on spike length. The highest spike length (9.2 cm) was recorded in treatment where 50% N was applied from mineral source (urea), 25% from poultry waste and 25% from municipal waste followed by treatment where 75% N was applied from mineral source (urea) and 25% were supplied from farmyard manure. Organic manures are excellent source for multi-nutrient supply to crop plants although in a variable manner depending on their type and quality and cause increase in spike length (Ahmad *et al.,* 2007).

Abbas *et al*. (2012) reported that 6 tons/ha poultry manure + recommended NPK (T4) had significantly higher spikes than the other treatments while control (T1), had the shortest spike length while the spike obtained at recommended NPK (T2) and 10 tons/ha FYM (T3) were at par. Days to 50% heading is an indication of uniformity of the material used, NPK combinations significantly increased days to 50% heading over control. Minimum days to 50% heading (114) were recorded in control. Linear increase in days to 50% heading was observed with increase in NPK levels and maximum days to 50% heading (117) were recorded at 80-60-60 kg NPK ha/ha (Rehman *et al*., 2010). Badaruddin *et al*. (1998) also reported no significant increase in days to 50% heading of wheat at 10t FYM compared with control.

Number of grains per spike is an important character for determining yield in wheat and it is greatly influence by crop nutrients (Hammad *et al*., 2011; Abdur *et al*., 2016). Zahoor (2014) observed that application of 10 t ha^{-1} FYM before sowing and FYM and nitrogen increased the number of grain per spike. The higher number of grains $spike^{-1}$ (56) was counted in the plots using 10 t ha^{-1} FYM before sowing while lower number of grains/spike from the control (43) plots. Similarly,Abbas *et al*. (2013)Akhtar *et al*. (2011) Ali *et al*. (2011) Hammad *et al*. (2011) Shah *et al*. (2010) and Rehman *et al*. (2008) Jan and Noor (2007)found that, NPK, FYM and FYM x NPK significantly affected grains $spike^{-1}$.

Thousand grain weights play significant role in economic yield. Hammad *et al*. (2011) reported maximum 1000-grain weight (37.65 g) was obtained where poultry litre at the rate of 20 ton ha^{-1} (T5) was used and minimum 1000-grain weight (24.80 g) was recorded in control, similar results were reported by Channabasanagowda *et al.* (2008) ; Rehman *et al*. (2008) ;Akhtar *et al*., 2011) ; Ali *et al*. (2011) ;Abbas *et al*. (2012) ; Abbas *et al*. (2013) ; Zahoor (2014) ; and Abdur *et al*. (2016). Shah *et al*. (2010) also recorded differential effect of applied N on thousand-grain weight over the control. Weight of 42.8 g was found in treatment where 25 % FYM and 25 % poultry manure were applied in combination with 50 % N from urea followed by treatment where 25 % FYM and 25 % city waste were applied with 50% of inorganic N.

Zahoor (2014) reported that grain yield of wheat is affected by the application of various organic and inorganic nitrogen sources applied alone and in various combinations and use of FYM with urea before sowing have the potential to enhance the yield of wheat. He also reported that plots having 10 t ha^{-1} FYM incorporated before sowing had increased the grain yield by 20 % over the control plots. Increasing N rates had increased grain yield, and maximum grain yield (5095 kg ha^{-1}) was recorded in plots having 90 kg N ha^{-1} compared to minimum N recorded in plots having no N (2428 kg ha^{-1}). Integrated use of organic fertilizer with inorganic fertilizer has extensively increased grain yield and also useful for sustainable crop growing production (Mandal *et al*., 2007; Hidayatullah *et al*., 2013). Similar results were reported by (Fan *et al*., 2005; Jan and Noor, 2007; Shah *et al*., 2010; Rehman *et al*., 2010; Akhtar *et al*., 2011; Ali *et al*., 2011; Hammad *et al*., 2011;Abbas *et al*., 2012 and Abbas *et al*., 2013; Abdur *et al*., 2016).

FYM and NPK used in combination improved grain yield by increasing tillers per m^2, early plant vigor, spikes per m^2 and biomass yield (Rehman *et al*., 2008). Abedi *et al*., (2010) also showed that, with increasing levels of nitrogen from 80 to 160 and 240 kg ha^{-1}, wheat grain yield significantly increased (52 %, 115 % and 95 % over control in 80, 160 and 240 kg N ha^{-1} treatments, respectively), compared to control.

Hammad *et al*. (2011) concluded that crop plants produce biological yield by utilizing available resources, significant increase in biological yield per hectare was observed as a result of application of different organic manures. However maximum biological yield (9.61 t ha^{-1}) was produced with the application of NPK at the rate of 160+100+50 kg ha^{-1} while minimum biological yield (4.67 t ha^{-1}) was obtained in control. Rehman *et al*. (2008) observed that, FYM, NPK and FYM x NPK significantly affected biological yield.

Hammad *et al*. (2011) got harvest index significantly different among the treatments, maximum harvest index (40.10 %) was examined in recommended NPK at the rate 160+100+50 kg/ha. Similarly, Abbas *et al*. (2013) observed that the use of FYM significantly increased biomass of wheat. The highest biomass yield (4996 kg fed^{-1}) obtained by applying FYM at 20 t ha^{-1} as compared to the lowest grain yield (10.0 t ha^{-1}) of the control.

2.7 Fertilizer and Sowing Method Interaction on Growth and Yield of Wheat Varieties

Significant interactions between organic and inorganic fertilizers on growth and yield of wheat have been reported. The interaction between manure and N fertilizer enhanced N (58-63%) recovery (Nyamangara *et al*., 2003). Khan*et al*. (2013b) reported organic and inorganic sources and their interactions were not significant on number of days to emergence. Rehman *et al*. (2010) observed significant interaction between NPK and FYM levels on wheat plant height. The highest plant height of 84.3 cm at 30 t FYM ha^{-1} and 80-60-60 kg NPK ha^{-1}, while shortest plants of 75.8 cm height were observed at no NPK and 30t FYM ha^{-1}.Khan*et al*. (2013a) also observed significant interaction between FYM x N on plant height. Nawab *et al*. (2006) reported significant interaction between FYM and inorganic fertilizers on leaf area of wheat. Khan*et al*. (2013b) reported significant interaction among FYM x N, Control (C) Vs Rest and PM x FYM x N significantly affected leaves tiller^{-1}. Interaction between FYM x N shows that increase of FYM and N levels linearly increased number of leaves per tiller up to 6 tons FYM ha^{-1} and 90 kg N ha^{-1}. In case of interaction PM x FYM x N leaves tiller^{-1} increased with increased level of FYM at 2 tons PM ha^{-1} with 60 kg N ha^{-1} while with 90 kg N ha^{-1} leaves tiller^{-1} decreased with increased level of FYM at 4 tone PM ha^{-1} and increased. Zahoor (2014) reported interaction (FYM x N) on number of grain spike^{-1} of wheat. Rehman *et al*. (2008) Interaction of FYM and NPK showed that maximum number of grain spike^{-1} (56.8) were recorded in plots which received 45 t FYM ha^{-1} and 80-60-60 kg NPK ha^{-1}, while minimum grains spike^{-1} (48.8) were recorded from control. Khan*et al*. (2013a) interaction between PM x N shows that increase of PM and N levels linearly increased days to maturity up to 6 tons FYM ha^{-1} and 90 kg N ha^{-1}. They also observed significant interaction in Y x FYM and Y x N on days to maturity.

Rehman *et al*. (2010) also reported significant NPK x FYM interaction on yield with maximum grain yield (2512 kg ha^{-1}) recorded from the application of 80-60-60 kg NPK ha^{-1} and 45 t FYM ha^{-1}, while minimum grain yield (2217 kg ha^{-1}) was recorded from plots where no NPK and 45 t FYM ha^{-1} were applied. They opined that sole application of either FYM or NPK is not advisable as none of them produced maximum grain. Combined application of FYM and NPK improved grain yield by increasing tillers m^{-2}, early plant vigour, spikes m^{-2} and biomass yield (Rehman & Khalil, 2008; Hossain *et al*., 2002). Rehman *et al*. (2008) also observed significant interaction of FYM and NPK on biological yield.

2.8 Correlation and Path Analysis of Wheat Growth and Yield

Correlation coefficients is the measure of degree of symmetrical association between two variables or characters and help us in understanding the nature and magnitude of association among yield and yield components (Khan and Naqvi 2012). It is a tool used by breeders to bring improvement in the desired trait. A crop breeding programme, aimed at increasing the plant productivity requires consideration not only of yield, but also of its components that have a direct or indirect bearing on yield. The coefficients of correlation describe the degree of association between independent and dependent variables. Path Coefficient analysis measures the direct influence of one variable upon another and permits the separation of correlation coefficient into components of direct and indirect effects (Jitendra and Devendra, 2011). The phenotypic correlations were normally of genetic and environmental interaction which provided information about the association between the two characters.

Path coefficient analysis is an important tool for partitioning the correlation coefficients into the direct and indirect effects of independent variables on a dependent variable. Hypothesized systems of causal relationships between yield components and yield can be tested using path analysis (Dewey and Lu, 1959).

Interdependency within and between characters and greatly determine the grain yield directly or otherwise. Ibrahim (2016); Mohammadi *et al*. (2016); Bagrei and Bybordi (2015);Poor *et al*. (2015); Onyibe (2000); Abubakar (1999) reported positive and significant correlation between grain yield and most growth and yield components of wheat. These include stand count m^{-2}, plant height, number of tillers plant $^{-1}$, LAI, crop dry matter, CGR, spike m^{-2}, spike length, spikelets spike^{-1}, number of grains spike^{-1}, weight of grains spike^{-1}, 1000 grain weight, total biomass and harvest index.

Khan *et al.* (2013a) ; Fellahi *et al.* (2013); Chhibber *et al*., (2014) also reported positive correlation between plant height as well as LAI with grain yield which implies that height and LAI facilitate interception of solar radiation by assimilatory organs for effective photosynthesis which form the basis for growth through dry matter production and subsequent yield increase. They also observed significant and positive correlation between LAI and CGR. Higher LAI result in higher interception of solar radiation and consequently improve photosynthetic activities for growth.

Earliness to 50% flowering, heading and maturity or short life cycle is important for wheat to utilize the cool season and elude terminal heat stress. Khan *et al*. (2013b) observed negative correlation of grain yield to days to 50% heading and maturity. Ibrahim (2016); Khan *et al*. (2013a); Abubakar (1999); Onyibe (2000) reported positive correlation between grain yield and its components showed that spike m^{-2}, number of grain spike^{-1}, weight of grains spike^{-1} and 1000 grain weight are important yield determinants. Negative correlation among yield and its components are regularized by compensation mechanism such as when fewer the grain spike^{-2}are produced, the average 1000 grain weight becomes heavier and vice versa (Ibrahim 2016; Abubakar 1999; Onyibe 2000).

The path analysis confirmed that direct effect of total biomass and harvest index (Bagrei and Bybordi (2015); Maleki*et al*. (2008) whereas, indirect effect of crop dry matter via weight of grain spike^{-1} as well as number of tillers plant^{-1} via total biomass. Previous studies have reported residual values of 0.31%- 38.70% suggesting that the major characters contributing to the grain yield of wheat were measured or otherwise (Khan and Naqvi, 2012; Meyari *et al*., 2013; Gelalcha and Hanchinal, 2013).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

Experiment was conducted at the farms of Institute for Agricultural Research, Ahmadu Bello University located at Samaru (11°11'N, 07°38'E, 686m above sea level) and the Irrigation Research Station Kadawa ($11^0$39'N, $08^0$27'E; 500m above sea level) located in the Northern Guinea and Sudan Savanna ecological zones of Nigeria, respectively, during 2014/2015 and 2015/2016 dry seasons. Soil samples were randomly collected from the experimental sites at a depth of 0-30 cm using a 10 cm diameter soil auger each year before land preparation. The samples were bulked, air dried, grounded, sieved and a composite sample was taken and subjected to physical and chemical analysis at the Department of Agronomy Laboratory, ABU, Zaria using method described by Association of Official analytical chemist (A.O.A.C., 2002). Farmyard Manure was purchased from National Animal Production Research Institute, (*NAPRI*), Shika,Ahmadu Bello University,*Zaria*, and analysed for N, P and K in both years using the same method. Meteorological data including daily temperature, sunshine hours, and relative humidity during the period of the experiment were obtained from meteorological stations of the Institute for Agricultural Research Samaru and irrigation research station Kadawa for the period of experiment (Appendix I and II).

3.2 Treatments and Experimental Design

The treatments consisted of two sowing methods (broadcasting and drilling), three varieties (LACRIWHIT-1, LACRIWHIT-4 and LACRIWHIT-5) and four fertilizer (zero fertilizer, recommended rate of NPK (120 kg N, 60 kg P_2O_5 and 60 kg K_2O ha^{-1}), Farmyard Manure (FYM) at 10 t ha^{-1} and combination of half dose each of NPK (60kg

N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}) and FYM (5 t ha^{-1})). The treatments were laid out in a Randomized Complete Block Design and replicated three times.

3.2.1 Description of varieties

Three wheat varieties used were obtained from Lake Chad Research Institute, Maiduguri, Borno State, Nigeria are described as follows by (LCRI, 2015).

LACRIWHIT–1 (Seri-M82)**:** Is the first variety released in 1997 and is a lowland and irrigated variety which thrives best in areas with temperature range of 18 to 25^{0}C. It is moderate in height, with high tillering ability, early maturing (80-90 days after sowing) and well adapted to Sahel and Sudan savanna ecological zones. It is moderately tolerant to stem borer and has a yield potential of 2 to 3 t ha^{-1}. The seeds are golden brown in colour and are of excellent baking quality.

LACRIWHIT–4 (Atilla Gan Atilla)**:** Is a lowland variety adapted to the Sahel, Sudan and Northern Guinea savannah zones with good ability to tolerate heat. It is medium maturing (85-90 days after sowing), with height of 70-80 cm and of medium tillering ability. It is moderately tolerant to stem borer and high yielding (4- 4.5 t ha^{-1}). Seeds are white in colour with good baking quality. LACRIWHIT–4 was released by the institute in the year 2008.

LACRIWHIT–5 (Norman)**:** It was released in the year 2014 and is a heat tolerant wheat variety suitable for Sahel, Sudan and Northern Guinea savannah zones. It is medium variety (110 to 115 days) and attain height of 90-95 cm. The seeds are red in colour having excellent baking qualities with yield potential of 5.0 to 6.0 t ha^{-1}.

3.3 Cultural Practices

3.3.1 Land preparation

The experimental fields were harrowed and ridged to obtain the desired tilth for proper germination and growth of the crop. Plots were marked out, labelled and made into sunken seed beds manually. The gross plot size was 3 x 4 m (12 m^2) and the net plot was 1.8 x 3.4m (6.12 m^2). A distance of 1.0 m and 0.5 m was allowed between replicates and plots, respectively.

3.3.2 Seeds and sowing

The seeds were treated with seed dressing chemical Apron-star (20% w/w thiamethoxam, 20% w/w metalaxyl-M and 2 % w/w difenoconazole), at the rate of 5 g kg^{-1} of seed to protect the seed from soil borne pests and diseases. Sowing was done as par treatments at seed rate of 100 kg ha^{-1} for both sowing methods. Drilling was done on rows spaced at 30 cm apart. The seeds were sown on 3rd and 10th December in 2014, and 2nd and 9th December in 2015 at Samaru and Kadawa, respectively.

3.3.3 Irrigation

The first irrigation was done immediately after seeding and subsequent irrigation at 7 days and 10 days interval was observed at Samaru and Kadawa, respectively, up to hard dough stage, after which it was stopped to ensure uniform maturity and easy harvesting. The method of irrigation used was check basin irrigation; each plot was irrigated to ensure provision of enough water to bring the soil to field capacity.

3.3.4 Fertilizer application

Fertilizer was applied according to the treatments. Farmyard Manure at 10 t ha^{-1}, NPK (120kg N, 60kg P_2O_5 and 60 kg K_2O ha^{-1}), half dose of FYM and NPK and zero fertilizer control. Pre-sowing irrigation was done and farmyard manure was incorporated into soil two weeks before sowing while for NPK, half of the N and all of P and K were applied at sowing using NPK 15:15:15. The remaining half N was applied five weeks after sowing (WAS) using urea (46%) as source of N.

3.3.5 Weed control

Weeds were controlled using pre-emergence herbicide butaclor (N-butaxymethyl-8-chloro-2, 6 diethy) at the rate of 2.5 kg a.i ha^{-1} a day after sowing and post-emergence herbicide 2,4-D (2,4-dichlorophenoxyacetic acid) at the rate of 2.5 kg a.i ha^{-1} three weeks after sowing. Supplementary hoe weeding and hand pulling were carried out at 6 weeks after sowing to control emerged sedges for drilled and broadcast treatments respectively.

3.3.6 Pest and disease control

There were no incidence of pests and diseases of economic importance throughout the period of the experiment.

3.3.7 Harvesting

The crop was harvested when plants attained physiological maturity i.e. when 70% peduncles had turned brown. Harvesting was done by cutting the plants with a sickle as close to the ground as possible to avoid substantial loss in biomass. The harvested plant from net plots were bundled into sheaves, dried in the field and threshed by beating with sticks, then winnowed. The grains were cleaned, dried and weighed to determine yield per plot

3.4 Data Collection

Five plants were tagged randomly within the net plot for recording growth parameters at 3, 6, 9, and 12 WAS for each parameter unless otherwise stated. Yield parameters were taken at harvest.

3.4.1 Stand count (plant m^{-2})

Number of plants was counted within a 0.25 metre square fourteen days after sowing in each plot and the results converted to per meter basis and recorded.

3.4.2 Plant height (cm)

Plant height was measured using a meter rule from ground level to tip of the longest leaf during vegetative growth and to the tip of the spikes after heading from each plot, and the data was recorded and averaged.

3.4.3 Number of tillers m^{-2}

Number of tillers m^{-2} was determined using from 0.25 metre square area in each plot and number of tillers was counted, recorded and extrapolated to a meter square basis. This was done at 6 WAS only.

3.4.4 Number of leaves $plant^{-1}$

Number of leaves from five (5) tagged plants was counted and the average number of leaves per plant later calculated and recorded.

3.4.5 Leaf area $plant^{-1}$ (cm^2)

Leaf area was determined using leaf area meter LI-3100C model. This was by destructive sampling from outside net plot. Three plants were used and from each plant, three leaves sample were cleaned and then passed through the machine's pulley and leaf area was read by the sensor and the mean was then recorded. The mean leaf area obtained was multiplied by the number of leaves per plant.

3.4.6 Leaf area index (LAI)

The mean leaf area per plant obtained was multiplied by the number of plant in a 0.25 metre square area and the results were converted to square meter by multiplying by four to get leaf area per meter square (cm^2). This was used to determine the leaf area index (LAI) by dividing it by the land area occupied by plant (cm^2).

$$\text{LAI} = \frac{\text{LeafAreaperPlant}}{\text{Landarea}}$$

3.4.7 Crop dry matter (g m^{-2})

Crop dry matter per m^2 was sampled from outside the net plot of each plot at 3, 6, 9 and 12 WAS. Plants in 0.5 x 0.5m were carefully cut at the base and shook to remove soil and other foreign particles. The samples were then oven dried at 70^0 C for 24 hours. The oven dried samples were weighed using top loading digital balance SB16001 TOLEDO model, and the dry matter values were recorded and dry matter reported and extrapolated to per m^2 basis.

3.4.8 Crop growth rate (g m^{-2} wk^{-1})

Crop growth rate (CGR) is the rate of dry matter production per plant per unit time. It was calculated by using the following formulae and expressed as g m^{-2} wk^{-1} at 6, 9 and 12 WAS as described by Radford (1967).

$$\text{CGR} = \frac{W2-W1}{t2-t1}\,\mathbf{g\ m^{-2}\ wk^{-1}}$$

Where w_1 and w_2 are dry weights in g m^{-2} at respective times t_1 and t_2 in weeks.

3.4.9 Relative growth rate (g g^{-1} wk^{-1})

This is the increase in plant material per unit of plant material per unit of time as described by Radford (1967). Relative growth rate (RGR) at various stages was calculated and expressed in g g^{-1} wk^{-1}. The formula used for the computation is as follows;

$$\text{RGR} = \frac{logeW\,2-logeW\,1}{t2-t1}$$

Where w_1 and w_2 are dry weights in g m^{-2} at respective times t_1 and t_2 in weeks and $\log_e$ represents natural logarithm.

3.4.10 Net assimilation rate (g cm^{-2} wk^{-1})

This expresses photosynthetic efficiency of assimilatory leaf surfaces. It is the rate of dry weight increase per unit leaf area per time. It was calculated using formulae suggested by Watson (1958) as follows at 6 and 9 WAS;

$$NAR = \frac{W2-W1}{t2-t1} x \frac{logeA\,2-logeA\,1}{A2-A1} \text{ g cm}^2 \text{ wk}^{-1}$$

Where w_1 and w_2 are dry weights in g m^{-2} at respective times t_1 and t_2 in weeks and log_e represents natural logarithm.A_1 and A_2 are respective leaf area (cm^2) in weeks

3.4.11 Days to 50% heading

The number of days to 50% heading was determined by counting number of days from sowing to period when 50% of the plants had formed spikes in each gross plot and the number was then recorded.

3.4.12 Days to 50% flowering

The number of days to 50% flowering was calculated by determining the difference in number of days from sowing to the time when 50% of the spikes have flowered in each gross plot.

3.4.13 Days to physiological maturity

The number of days to physiological maturity was determined by counting from day of sowing to the time when 50% of the peduncle have turned golden brown in each gross plot.

3.4.14 Effective grain filling period (days)

The effective grain filling period is the difference between number of days to 50% flowering to number of days to physiological maturity in each gross plot.

3.4.15 Effective tiller m^{-2}

Effective tillers are panicle bearing tillers. This was determined by counting panicle bearing tillers in a 0.25 metre square area in each plot and the results were converted to square meter.

3.4.16 Number of spike m^{-2}

This was determined by counting the number of spikes in a 0.25 metre square area in each plot and results extrapolated to square meter basis and were recorded.

3.4.17 Spike length (cm)

Spike length was measured from 5 sampled plants from each plot using ruler from basal node of spike to tip of topmost spikelet and the mean values recorded.

3.4.18 Number of spikelets spike^{-1}

The number of spikelets from the five sampled spikes from each plot was counted and the average recorded.

3.4.19 Number of grain spike^{-1}

The number of grains per spike from the five sampled plants from each plot was counted and the average recorded.

3.4.20 Weight of grain spike^{-1} (g)

The weight of grain from the five sampled spikes from each plot was measured using a digital balance (SB16001 TOLEDO model) and the average was recorded.

3.4.21 1000 grain weight (g)

Two samples of 250 of grain was taken from each plot and weighed using digital balance (SB16001 TOLEDO model) then the values were averaged and multiplied by 4 to determine the 1000-grain mass.

3.4.22 Grain yield (kg ha^{-1})

The harvested plants from net plot were threshed, winnowed, cleaned and weighed using using digital balance (SB16001 TOLEDO model). The values obtained from each plot were then converted to kilogramme per hectare basis and recorded.

3.4.23 Biomass yield (kg ha^{-1})

The total above ground biomass yield (grain and straw) was obtained by tying and weighing the harvested plants from net plots using balance scale. The values for each net plot obtained were converted to kilogramme per hectare basis and recorded.

3.4.24 Harvest index (%)

The harvest index was determined by dividing the grain yield by the biomass yield (grain and straw) per net plot basis and values recorded.

Harvest Index = $\frac{\text{Grain Yield}}{\text{Biomass yield}}$ **x** $\frac{100}{1}$

3.5 Grain Proximate and Gluten Content Analysis

3.5.1 Grain proximate analysis

Proximate analysis was carried out at analytical laboratory, Department of Agronomy, A B U, Zaria using (A.O.A.C., 2002) procedure to determine moisture content (%), ash content (%), fibre content (%), lipid content (%), protein content (%) and carbohydrate content (%).

3.5.2 Grain gluten content analysis

Whole wheat flour was used to determine grain gluten content according to the standard method (AACC 1983) then the isolated drying gluten contained was evaluated. This was done at the National Agency for Food and Drug Administration and Control (NAFDAC) Zonal laboratory, Maiduguri, Borno state.

3.6 Partial Economics Analysis

The grain yield data was subjected to partial economic analysis where return and variable cost were computed to determine the gross margin. The gross margin was calculated based on procedure described by Olukosi and Erhabor (1988) as follows:

GM=TR-TVC

Where GM=gross margin

TR=total revenue

TVC=total variable cost

Olukosi and Erhabor (1988)

Return on investment was also computed as follows:

$$\text{ROI} = \frac{netreturn}{\text{TVC}} x \frac{100}{1}$$

Where ROI=return on investment

Net return=total revenue (yield x output price)-TVC

Olukosi and Erhabor (1988)

3.7 Statistical Analysis

Data collected were subjected to Analysis of Variance (ANOVA) as described by Gomez and Gomez (1984) using General Linear Model procedure (GLM) of the Statistical Analysis System (SAS) package (SAS, 1990) and treatment means were compared using Duncan's Multiple Range Test (DMRT) at 5 % probability level (Duncan, 1955). The relationships between characters were assessed through simple correlation analysis (Little and Hill, 1978). Individual and combined contributions to grain yield of some selected characters of wheat were determined using path coefficient analysis as described by Dewey and Lu (1959).

CHAPTER FOUR

4.0 RESULT

4.1 Soil, Farmyard Manure Analysis and Weather Data

The results of physical and chemical properties of soils at Samaru and Kadawa during 2014/2015 and 2015/2016 dry seasons are shown in Table 1. The soil at Samaru was loam and slightly acidic with Ph range of 6.01 to 6.20. The soil nutrient status was 1.30-1.34 g kg^{-1} of organic carbon, 0.15 to 0.35g kg^{-1} of total nitrogen, 3.49-3.53 g kg^{-1} of available phosphorus and K was between 0.015 to 0.13 cmol kg^{-1}. Exchangeable bases were 2.1 to 3.15 cmol kg^{-1} of Ca, 0.90-1.60 cmol kg^{-1} of Mg, 0.17 to 0.35 cmol kg^{-1} of Na as well as CEC of 3.10 to 3.40 cmol kg^{-1} of soil. At Kadawa, the soil was characterized as sandy loam and slightly acidic with Ph ranging from 6.22 to 6.44, organic carbon of 1.18 to 1.70 g kg^{-1}, total nitrogen 0.19 to 0.53 g kg^{-1}, available phosphorus 5.89 to 6.04 g kg^{-1}, potassium content ranging from 0.07 to 0.08 cmol kg^{-1}, while the exchangeable bases were in the range of 2.86 – 4.00 cmol kg^{-1} Ca, 0.71 to 1.30 cmol kg^{-1} Mg, 0.52 to 0.54 cmol kg^{-1} Na and CEC in the range of 2.30 to 4.16 cmol kg^{-1} of soil.

The chemical composition of Farmyard Manure in 2014/2015 and 2015/2016 is presented in Table 2. The nutrient composition showed high amount of total nitrogen which ranges from 2.1 to 2.34 g kg^{-1}, total phosphorus 0.38-0.92 g kg^{-1} and potassium in the range of 1.1-1.66 g kg^{-1} while in 2014/2015 season Ca and Mg were 0.41 and 0.01 g kg^{-1}.

The weather data during the experimental period are shown in Appendices I and II. Maximum temperature from December to April in Samaru ranged from 23.0 to 40.0^{0}C in 2014/2015 and 27.4 to 40.4^{0}C in 2015/2016 while minimum temperature ranged from 12.0 to 24.0^{0}C in 2014/2015 and 13.6 to 26.3^{0}C in 2015/2016. Relative humidity ranged

Table 1: Physical and chemical properties of soils at experimental sites in Samaru and Kadawa during 2014/2015 and 2015/2016 dry seasons

	Samaru		Kadawa	
Composition	2014/2015	2015/2016	2014/2015	2015/2016
Physical Properties (g kg^{-1})				
Sand	440	530	660	670
Silt	340	350	200	230
Clay	220	120	140	100
Textural class	Loam	Loam	Sandy Loam	Sandy Loam
Chemical Properties				
Ph(in H_2O)	6.20	6.01	6.44	6.22
Ph (in 0.01M. $CaCl_2$)	4.51	5.56	5.05	5.74
Organic carbon (g kg^{-1})	1.30	1.34	1.70	1.18
Available phosphorus (mg kg^{-1})	3.49	3.53	6.04	5.89
Total nitrogen (g kg^{-1})	0.35	0.15	0.53	0.19
Exchangeable base (cmol kg^{-1})				
Ca^{++}	3.15	2.31	4.0	2.86
Mg^{++}	1.60	0.90	1.30	0.71
K^{++}	0.13	0.015	0.08	0.07
Na^{++}	0.35	0.17	0.54	0.52
CEC	3.10	3.40	3.30	4.16

Soil sample analyzed at analytical laboratory, Department of Agronomy, A B U, Zaria

Table 2: Chemical composition of Farmyard Manure used for the experiment in 2014/2015 and 2015/2016 dry seasons

Chemical Composition (%)	2014/2015	2015/2016
N	2.1	2.34
P	0.38	0.92
K	1.66	1.10
Ca	0.41	Not analysed
Mg	0.01	Not analysed

Farmyard Manure analyzed at analytical laboratory, Department of Agronomy, A B U, Zaria between 2.0 and 36.0% and 11.4 to 57.6 % in 2014/2015 and 2015/2016, respectively. Daily pan evaporation ranged from 6.8 to 13.6 mm day^{-1} in 2014/2015 and 7.1 to 15.3 mm day^{-1} in 2015/2016 while the mean sunshine hours were 6.9 and 7.8 hrs day^{-1} in 2014/2015 and 2015/2016, respectively. At Kadawa the average maximum temperature ranged from 21.8^{0}C to 37.6^{0}C in 2014/2015 and 26.3^{0}C to 39.7^{0}C in 2015/2016. The relative humidity ranged from 5 to 23 % and 20.1 to 47 % in 2014/2015 and 2015/2016, respectively. Also the daily pan evaporation ranged from 2.9 to 22.0 mm day^{-1} in 2014/2015 and 5.5 to 10.4 mm day^{-1} in 2015/2016 and the mean sunshine hours were 8.9 and 8.2 hrs day^{-1} in 2014/2015 and 2015/2016, respectively.

4.2 Crop Parameters

4.2.1 Stand count m^{-2}

Table 3 shows the effects of sowing method and fertilizer on stand count of three wheat varieties at Samaru and Kadawa in 2014/2015 and 2015/2016 dry seasons. Difference in stand count among varieties was significant only at Kadawa in 2014/2015 and the combined mean. In both LACRIWHIT-4 recorded significantly more stands then LACRIWHIT-1 while it was statistically at par with LACRIWHIT-5. Sowing method effect on stand count was significant only in 2015/2016 and the means at Kadawa when drilled produced more stands than those broadcasted.

Fertilizer application recorded significant effect on wheat stand count throughout the study except at Samaru in 2014/2015 season. Application of NPK alone consistently recorded more stands except at Samaru (2015/2016 and mean) where it was similar to application of FYM alone. The control treatment significantly produced least stands except at Kadawa (2014/2015 season) where it was similar to application of FYM alone.

Table 3: Stand count m^{-2} of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	Stand count m^{-2}					
	Samaru			**Kadawa**		
Treatment	2014-15	2015-16	combined	2014-15	2015-16	combined
Variety (V)						
LACRIWHIT-1	234.67	201.17	217.92	230.00b	257.50	243.75b
LACRIWHIT-4	251.50	209.92	230.71	252.00a	301.17	276.58a
LACRIWHIT-5	218.83	205.13	211.98	240.33ab	258.33	249.33ab
SE±	13.525	9.931	9.085	6.070	15.907	9.742
Sowing Method (S)						
Broadcast	237.11	203.94	220.53	243.67	226.89b	235.28b
Drill	232.89	206.86	219.88	237.89	317.78a	227.83a
SE±	11.043	8.109	7.418	4.960	12.988	7.954
Fertilizer (F)						
Control	214.22	135.44c	174.83c	217.33c	222.22b	219.78c
NPK (120:60:60 kg ha^{-1})	261.56	246.89a	254.22a	271.33a	325.78a	298.56a
FYM (10 t ha^{-1})	237.78	227.78ab	232.78ab	234.89bc	273.33b	254.11b
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	226.44	211.50b	218.97b	239.56b	268.00b	253.78b
SE±	15.617	11.467	10.490	4.960	18.368	11.249
Interaction						
Vx S	NS	*	*	NS	*	*
V x F	NS	NS	NS	NS	NS	NS
S x F	NS	*	NS	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

Significant treatment interaction of variety and sowing method on wheat stand count was recorded in 2015/2016 and the combined mean at both locations. Interaction between sowing method and fertilizer was also significant at Samaru in 2015/2016 season (Tables 4 and 5).

In 2015/2016 at Samaru, LACRIWHIT-4 and LACRIWHIT-5 when drilled or broadcasted recorded similar and more stand count than LACRIWHIT-1. However, LACRIWHIT-5 was at par with LACRIWHIT-1 throughout and broadcasted LACRIWHIT-4 were similar to drilled LACRIWHIT-1. Variation in sowing method had no significant effect on stand count of each of the varieties. The highest and the least stand count was from drilled LACRIWHIT-4 and broadcast LACRIWHIT-1, respectively. In the combined means at Samaru, significantly higher stand count was recorded in all the varieties when drilled and when LACRIWHIT-4 and 1 were broadcasted. However, broadcasted LACRIWHIT-5 was at par with drilled LACRIWHIT-4 and 1 at both sowing methods (Table 4).

At Kadawa in 2015/2016, all the varieties were similar and having more stand count when drill and were at par with broadcasted LACRIWHIT-4. Similar trend was observed at Kadawa in the combined mean (Table 4). Table 5 shows the interaction between sowing method and fertilizer at Samaru in 2015/2016 dry season. When only NPK fertilizer was applied, drilled wheat had more stand count which was at par with broadcast supplied with combined NPK and FYM. On the other hand, the fertilized broadcast were at par with the drill when supplied with FYM alone.

4.2.2 Plant height (cm)

Table 6 and 9 shows effects of sowing method and fertilizer on plant height of wheat varieties in 2014/2015 and 2015/2016 dry seasons at Samaru and Kadawa respectively. At Samaru, significant differences in height among varieties was recorded throughout

Table 4: Variety and sowing method interaction on stand count m^{-2} of wheat at Samaru and Kadawa in 2015/2016 dry season and the combine mean

	Variety		
Treatment	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Sowing Method		**Samaru 2015/2016**	
Broadcast	176.17c	221.67ab	198.17abc
Drill	188.34bc	234.08a	214abc
SE± 19.862			
		Samaru Combine	
Broadcast	226.83ab	242.50a	192.25b
Drill	209.00ab	218.92ab	231.71a
SE± 18.169			
		Kadawa 2015/2016	
Broadcast	178.67b	291.67a	210.33b
Drill	336.33a	310.67a	306.33a
SE± 31.814			
		Kadawa Combine	
Broadcast	205.67b	275.33a	224.83b
Drill	281.83a	277.83a	273.83a
SE± 19.484			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Table 5: Sowing method and fertilizer interaction on stand count of wheat at Samaru in 2015/2016 dry season

Treatment	**Sowing Method**	
	Broadcast	Drill
Fertilizer		
Control	138.67d	132.22d
NPK (120: 60:60 kg ha^{-1})	212.89bc	280.89a
FYM (10 t ha^{-1})	226.22b	229.33b
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	249.67ab	173.33cd
SE± 22.935		

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Table 6: Plant height (cm) of wheat varieties as influenced by sowing method and fertilizer application at Samaru in 2014/2015 and 2015/2016 dry season

Treatment	2014/2015					2015/2016				
	3WAS	6WAS	9WAS	12WAS	HARVEST	3WAS	6WAS	9WAS	12WAS	HARVEST
Variety (V)										
LACRIWHIT-1	5.67	18.01a	59.54a	67.23a	78.03a	3.00a	18.58a	46.31a	49.08ab	64.56
LACRIWHIT-4	5.71	17.76a	55.20b	67.15a	71.63b	2.60b	10.51b	40.46b	51.28a	63.96
LACRIWHIT-5	5.68	10.32b	37.89c	55.53b	61.89c	2.47b	8.51c	39.26b	47.38b	62.21
SE±	0.164	0.488	0.729	0.751	0.829	0.134	0.539	1.032	0.827	0.898
Sowing Method (S)										
Broadcast	5.70	15.28	50.58	62.51	70.29	2.72	12.26	41.40	49.53	62.75
Drill	5.67	15.45	51.17	64.08	70.74	2.66	12.81	42.62	48.96	64.42
SE±	1.340	0.399	0.595	0.613	0.667	0.109	0.440	0.842	0.675	0.733
Fertilizer (F)										
Control	5.69	10.44d	38.10c	55.07d	62.16c	1.73d	7.05d	29.69d	41.82d	59.80c
NPK (120: 60:60 kg ha^{-1})	5.83	19.12a	56.74a	68.95a	78.09a	3.68a	17.38a	51.46a	56.07a	71.84a
FYM (10 t ha^{-1})	5.78	14.85c	51.84b	62.97c	71.55b	2.17c	11.07c	39.87c	47.46c	57.97c
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	5.44	17.04b	56.82a	66.20b	70.27b	3.19b	14.64b	47.02b	51.63b	64.71b
SE±	0.036	0.564	0.841	0.867	0.958	0.155	0.622	1.191	0.954	1.036
Interaction										
Vx S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
V x F	NS	NS	*	**	NS	NS	*	NS	NS	NS
S x F	NS	NS	NS	NS	NS	NS	*	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

sampling periods except at 3 WAS in 2014/2015 and at harvest in 2015/2016 (Table 6). At other sampling periods LACRIWHIT-1 and 4 varieties statistically produced similar and taller plants than LACRIWHIT-5 except at 9 WAS and at harvest in 2014/2015 where LACRIWHIT-1 excelled LACRIWHIT-4 in 2014/2015. In 2015/2016, LACRIWHIT-1 produced taller plants than LACRIWHIT-4 and 5 except at 12 WAS when they were at par. LACRIWHIT-4 and 5 were at par except at 6 and 12 WAS when LACRIWHIT-4 excelled.

Sowing method had no significant effect on plant height of wheat varieties throughout the sampling periods of both season in Samaru. However, significant effect of fertilizer was recorded on wheat plant height throughout except at 3 WAS in 2014/2015. Application of NPK alone consistently produced taller plants than other fertilizer rates throughout the study except at 9 WAS in 2014/2015 season when it was at par with combined application of NPK and FYM. In 2015/2016, application of NPK alone produced taller plants than other fertilizer rates throughout the study and was followed by combined application of NPK and FYM which was in turn followed by application of FYM alone.

The interaction between variety and fertilizer on plant height was significant at 9 and 12 WAS in 2014/2015 and at 6 WAS in 2015/2016 season (Table 7), likewise the interaction between sowing method x fertilizer on plant height at 6 WAS in 2015/2016 season was also significant (Table 8).

At 9 WAS in 2014/2015, when either NPK or FYM alone was applied, LACRIWHIT-4 and 1 recorded similar and taller plants than LACRIWHIT-5. However, when combined application of NPK and FYM was made, LACRIWHIT-1 excelled in plant height followed by LACRIWHIT-4 (Table 7). At 12 WAS, LACRIWHIT-4 and

Table 7: Variety and fertilizer interaction on plant height (cm) of wheat at 9 and 12 WAS in 2014/2015 and at 6 WAS in 2015/2016 dry season at Samaru

Treatment	**Variety**		
	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Fertilizer	**2014/2015 (9 WAS)**		
Control	49.56d	39.44f	25.30g
NPK (120: 60:60 kg ha^{-1})	65.83a	62.17ab	42.22ef
FYM (10 t ha^{-1})	57.12c	58.20bc	40.20ef
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	65.66a	60.98bc	43.82e
SE± 2.061			
	12 WAS		
Control	61.61cd	54.49e	49.12f
NPK (120: 60:60 kg ha^{-1})	71.76ab	74.82a	60.27cd
FYM (10 t ha^{-1})	64.50c	69.80b	54.61e
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	71.00ab	69.48b	58.12de
SE± 2.124			
	2015/2016 (6 WAS)		
Control	11.34de	4.86g	4.94g
NPK (120: 60:60 kg ha^{-1})	24.90a	16.33c	10.92de
FYM (10 t ha^{-1})	17.61ab	8.88ef	6.72fg
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	20.50b	11.97d	11.44de
SE± 1.524			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Table 8: Sowing method and fertilizer interaction on plant height (cm) at 6 WAS at Samaru in 2015/2016 dry season

Treatment	**Sowing Method**	
	Broadcast	Drill
Fertilizer		
Control	7.04e	7.06e
NPK (120: 60:60 kg ha^{-1})	18.74a	16.06b
FYM (10 t ha^{-1})	10.16d	11.98cd
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	13.11c	16.17b
SE± 1.245		

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

LACRIWHIT-1 varieties were at par again when either NPK was applied alone or in combination with FYM. LACRIWHIT-4 excelled LACRIWHIT-1 when FYM alone was applied. This trend was reversed with the control (Table 7).

In 2015/2016 at 6 WAS, LACRIWHIT-1 consistently produced taller plants than either LACRIWHIT-4 or LACRIWHIT-5 irrespective of the fertilizer applied. The other two varieties were at par in height at all fertilizer rates except NPK alone. Application of NPK alone produced taller wheat plants than other fertilizers irrespective of variety adopted, except in LACRIWHIT-1 and 5 when FYM alone or combined with NPK was applied (Table 7).

In 2015/2016 season, the fertilizer x sowing method interaction revealed that broadcast plants produced taller plants than drilled sowing when NPK alone was applied. This trend was reversed with combined application of NPK and FYM. When sowing method was fixed, and effect of various fertilizers studied, application of NPK alone resulted in taller plants followed by combined application of NPK and FYM. There was no difference in height when no fertilizer was applied under both sowing methods (Table 8).

Table 9 shows plant height of wheat varieties as influenced by sowing method and fertilizer application at Kadawa in 2014/2015 and 2015/2016 dry seasons. The varieties differed in height at all the sampling periods except at 12 WAS and at harvest in 2015/2016 season. LACRIWHIT-1 and LACRIWHIT-4 were at par and produced taller plants than LACRIWHIT-5 at all sampling periods except at harvest in 2014/2015 and at 6 WAS in 2015/2016 when

Table 9: Plant height (cm) of wheat varieties as influenced by sowing method and fertilizer application at Kadawa in 2014/2015 and 2015/2016 dry season

	2014/2015					2015/2016				
Treatment	3WAS	6WAS	9WAS	12WAS	HARVEST	3WAS	6WAS	9WAS	12WAS	HARVEST
Variety (V)										
LACRIWHIT-1	4.70ab	24.10a	67.06a	75.80a	85.21a	3.69a	14.85a	57.94a	69.58	71.68
LACRIWHIT-4	4.47a	23.16a	64.40a	73.32a	77.72b	3.66a	10.53b	53.53a	69.82	71.97
LACRIWHIT-5	4.44b	12.56b	52.52b	67.93b	73.63c	3.19b	10.02c	43.85b	68.57	70.54
SE±	6.070	0.132	0.734	1.316	1.124	0.132	0.518	1.684	1.059	1.408
Sowing Method (S)										
Broadcast	4.64	19.68	61.33	71.62	77.91	3.55	11.75a	49.93	71.08a	72.23
Drill	4.70	20.19	61.32	73.08	79.80	3.47	9.85b	53.62	67.57b	70.56
SE±	0.107	0.599	0.931	0.918	0.677	0.108	0.518	1.375	0.864	1.150
Fertilizer (F)										
Control	4.72	14.76b	52.29b	65.29c	70.26c	3.03b	8.54c	43.67c	62.80c	66.67c
NPK (120: 60:60 kg ha^{-1})	4.56	22.59a	65.65a	77.57a	82.97a	4.02a	13.78a	66.59a	79.30a	80.07a
FYM (10 t ha^{-1})	4.77	20.73a	63.05a	71.74b	77.85b	3.21b	10.34b	43.80c	65.96bc	66.91c
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	4.63	21.66a	64.31a	74.82ab	84.33a	3.78a	10.54b	53.04b	69.24b	71.94b
SE±	0.152	0.847	1.316	1.298	0.958	0.153	0.598	1.945	1.223	1.626
Interaction										
Vx S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
V x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x F	NS	NS	NS	NS	NS	NS	**	NS	NS	**
V x S x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

LACRIWHIT-1 was superior to LACRIWHIT-4. The effect of sowing method was significant on plant height only at 6 and 12 WAS in 2015/2016 season when broadcast produced taller plants than drill sowing.

Fertilizer application had significant effect on plant height in both seasons except at 3 WAS in 2014/2015. At 6 and 9 WAS in 2014/2015, fertilized plants were at par in height and taller than unfertilized plants. At 12 WAS and at harvest, application of NPK alone and in combination with FYM were at par and had taller plants than FYM alone which was also taller than the control. In 2015/2016, application of NPK alone consistently produced tallest plants than other rates except at 3 WAS when it was at par with application of NPK in combination with FYM. The sowing method x fertilizer was significant on plant height at 6 WAS and at harvest in 2015/2016 only (Table 10). At 6 WAS, when broadcast sowing was adopted, application of NPK alone produced tallest plants followed by application of FYM alone which was at par with other combinations of fertilizer and sowing method except FYM alone x drill and broadcast sowing with no fertilizer. At harvest application of NPK alone again recorded taller plants in both sowing method but at par with drill supplied with combined NPK and FYM (Table 10).

Table 10: Interaction between sowing method and fertilizer on plant height (cm) of wheat at 6 WAS and at harvest in 2015/2016 dry season at Kadawa

Treatment	**Sowing Method**	
	Broadcast	Drill
Fertilizer	**6 WAS**	
Control	7.03d	10.65bc
NPK (120: 60:60 kg ha^{-1})	17.12a	10.44bc
FYM (10 t ha^{-1})	12.05b	8.62cd
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	10.78bc	10.29bc
SE± 1.196		
	At Harvest	
Control	69.22c	64.11d
NPK (120: 60:60 kg ha^{-1})	77.89ab	82.26a
FYM (10 t ha^{-1})	66.07cd	67.74cd
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	69.07c	74.81b
SE± 2.299		

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

4.2.3 Number of leaves plant $^{-1}$

Table 11 presents number of leaves per wheat plant as affected by treatments and their interaction at both Samaru and Kadawa in 2014/2015 and 2015/2016 dry season. In 2014/2015, varietal variation were significant at 3 and 9 WAS (Samaru) and 3 and 6 WAS (Kadawa). At Samaru, LACRIWHIT-5 produced more leaves than LACRIWHIT-4. Similar trend was observed at Kadawa (3 WAS) whereas at 6 WAS, LACRIWHIT-4 significantly produced more number of leaves than LACRIWHIT-1 and LACRIWHIT-5 which were also similar.

Sowing method had significant effect on number of leaves at 6 and 9 WAS (Samaru) and at 3 and 9 WAS (Kadawa) in 2014/2015 and at 3, 6 and 9 WAS at Kadawa in 2015/2016 season. At these periods, drill sowing significantly produced more number of leaves than broadcast.

Fertilizer application was significant on number of leaves at all sampling periods in both seasons and locations except at 9 WAS at Kadawa (2015/2016). Application of NPK alone consistently produced more number of leaves though at par with combined application of NPK and FYM at 3 and 6 WAS (2014/2015) and 9 WAS (2015/2016) at Samaru. Similar trend was observed at Kadawa (3 and 9 WAS) in 2014/2015 and also (6 WAS) in 2015/2016. At other sampling periods, application of NPK alone was followed by combined application of NPK and FYM and then FYM alone. Significant variety and fertilizer interaction on number of leaves was observed (6 WAS) at Kadawa in 2014/2015 season (Table 12). It was observed that when any of varieties was considered, application NPK alone resulted in the highest leaf number though at par with combined NPK and FYM except for LACRIWHIT-4 which the combined fertilizer.

Table 11: Number of leaves per plant of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	Samaru						Kadawa					
	2014/2015			2015/2016			2014/2015			2015/2016		
Treatment	3WAS	6WAS	9WAS	3WAS	6WAS	9WAS	3WAS	6WAS	9WAS	3WAS	6WAS	9WAS
Variety (V)												
LACRIWHIT-1	4.95ab	9.16	15.47b	5.69	10.70	11.87	8.14b	9.54b	9.22	6.20	11.37	15.56
LACRIWHIT-4	4.68b	8.65	14.36b	6.07	12.38	11.94	8.61b	14.04a	9.59	6.43	11.33	16.25
LACRIWHIT-5	5.20a	9.02	19.47a	5.84	12.78	12.28	10.15a	10.49b	9.39	6.88	13.34	17.54
SE±	0.130	0.190	0.468	0.377	0.724	0.596	0.235	0.347	0.221	0.418	0.842	0.871
Sowing Method (S)												
Broadcast	4.86	8.71b	15.52b	5.80	11.69	11.41	8.45b	10.98	9.11b	5.81b	10.03b	14.77b
Drill	5.03	9.18a	17.34a	5.93	12.21	12.66	9.48a	11.73	9.69a	7.21a	13.99a	18.13a
SE±	0.106	0.155	0.382	0.308	0.591	0.486	0.192	0.283	0.181	0.341	0.687	0.711
Fertilizer (F)												
Control	3.49c	6.54c	10.63d	3.93c	8.41c	9.96c	6.10c	8.02d	6.82c	4.92c	8.29c	14.70
NPK (120: 60:60 kg ha^{-1})	5.86a	10.52a	20.63a	8.46a	17.40a	13.87a	11.06a	14.67a	11.29a	8.68a	15.60a	16.90
FYM (10 t ha^{-1})	4.78b	8.60b	15.33c	4.17c	9.30c	11.68bc	8.34b	9.90c	8.64b	5.31c	10.89bc	17.22
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	5.66a	10.11a	19.08b	6.91b	12.68b	12.62ab	10.36a	12.84b	10.84a	7.11b	13.27ab	16.78
SE±	0.150	0.220	0.540	0.436	0.836	0.688	0.271	0.400	0.256	0.482	0.972	1.006
Interaction												
Vx S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
V x F	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS
S x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

Table 12: Interaction between variety and fertilizer on number of leaves plant-[1] in 2014/2015 dry season at Kadawa

Treatment	**Variety**		
	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Fertilizer			
Control	7.38c	8.83e	7.83e
NPK (120: 60:60 kg ha^{-1})	11.02cd	20.08a	12.92c
FYM (10 t ha^{-1})	8.62e	11.75c	9.33de
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	12.00cd	15.50b	11.88c
SE± 0.980			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

4.2.4 Leaf area (cm^2)

Leaf area of wheat varieties as affected by sowing method and fertilizer application during 2014/2015 and 2015/2016 dry seasons at Samaru and Kadawa is shown in Table 13. There was significant difference among the varieties at Samaru only in 2014/2015 and at Kadawa in both seasons except at 3 WAS in 2015/2016 season. LACRIWHIT-4 produced larger leaf area followed by LACRIWHIT-1 and LACRIWHIT-5 at 3 WAS, at 6 WAS LACRIWHIT-1 and 4 were at par in leaf area at Samaru, 2014/2015. At 9 WAS, the two varieties were similar and excelled LACRIWHIT-4 in leaf area. At Kadawa, 3 WAS, LACRIWHIT-5 was superior to LACRIWHIT-1 and 4 and LACRIWHIT-1 was superior to LACRIWHIT-4. At subsequent periods, LACRIWHIT-4 recorded larger leaf area throughout except in 2015/2016 when it was at par with LACRIWHIT-5 at 6 WAS and when LACRIWHIT-5 excelled LACRIWHIT-1 and 4. Drill sowing recorded larger leaf area compared to broadcast throughout period of experiment although the results were not always significant. Fertilizer application had significant effect on wheat leaf area in both seasons and locations. Application of NPK alone recorded larger leaf area than other fertilizer treatments though at par with NPK and FYM combined at 3 and 6 WAS (Samaru) and at 6 and 9 WAS (Kadawa) in 2014/2015. At other periods, it was followed by application of FYM alone.

Table 13: Leaf area per plant of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa, 2014/2015 and 2015/2016 dry seasons

	Samaru						Kadawa					
	2014/2015			2015/2016			2014/2015			2015/2016		
Treatment	3WAS	6WAS	9WAS	3WAS	6WAS	9WAS	3WAS	6WAS	9WAS	3WAS	6WAS	9WAS
Variety (V)												
LACRIWHIT-1	21.37b	90.63a	210.30a	15.05	66.93	121.46	59.90b	98.35b	118.60c	23.09	80.95b	188.08b
LACRIWHIT-4	29.24a	87.06a	152.77b	15.79	73.26	128.38	45.00c	209.96a	183.95a	21.05	85.17ab	193.78b
LACRIWHIT-5	16.52c	68.83b	206.64a	17.75	80.13	129.81	69.66a	97.13b	134.78b	25.99	112.08a	241.72a
SE±	1.213	3.088	10.402	1.865	6.841	9.848	2.109	5.764	4.481	2.629	9.496	14.892
Sowing Method (S)												
Broadcast	19.82b	77.71b	189.55	14.16	63.70b	116.55	54.89b	122.19b	141.55	25.27	102.11	221.41
Drill	24.93a	86.67a	190.26	18.24	83.19a	136.55	61.49a	142.78a	150.0	21.49	83.36	194.31
SE±	0.990	0.522	8.493	1.523	5.585	8.041	1.722	4.706	3.659	2.146	7.753	12.160
Fertilizer (F)												
Control	9.82c	33.98c	84.78d	5.37c	30.20c	79.62c	28.26d	69.69c	87.89c	14.16b	49.40c	171.74b
NPK (120: 60:60 kg ha^{-1})	30.85a	113.27a	293.91a	30.31a	147.43a	182.51a	82.82a	176.43a	182.49	34.51a	144.95a	228.79a
FYM (10 t ha^{-1})	20.67b	72.80b	146.38c	6.75c	41.74c	96.43c	46.83c	116.13b	135.52b	16.50b	75.46bc	215.49ab
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	28.17a	108.64a	234.52b	22.37b	74.41b	147.65b	74.83b	167.67a	177.21a	28.34a	101.13b	215.42ab
SE±	1.401	3.566	12.011	2.153	7.899	11.371	0.435	6.655	5.175	3.035	10.965	17.196
Interaction												
Vx S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
V x F	*	*	NS	NS	NS	NS	**	**	NS	NS	NS	NS
S x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

The variety x fertilizer interaction on leaf area was significant at 3 and 6 WAS in both locations in 2014/2015 (Table 14). In Samaru at 3 WAS, application of NPK either alone or in combination with FYM to LACRIWHIT-4 produced similar and larger leaf area than other variety and fertilizer combination. This was followed by application of NPK alone or combined with FYM to LACRIWHIT-1 which was at par with LACRIWHIT-4 with FYM alone. The least leaf area was recorded by LACRIWHIT-5 at zero fertilizer which was similar to LACRIWHIT-1 with zero fertilizer. At 6 WAS in Samaru, application of NPK alone or combined with FYM to LACRIWHIT-1 and 4 resulted in larger leaf area followed by LACRIWHIT-5 with NPK alone or combined with FYM which was at par with LACRIWHIT-1 with FYM alone. Similar response was observed in all the varieties when no fertilizer was applied. In Kadawa at 3 WAS, LACRIWHIT-4 and LACRIWHIT-5 produced similar and larger leaf area when NPK alone or combined with FYM was applied. LACRIWHIT-1 excelled when NPK alone was applied. All the varieties recorded smaller and similar leaf area when no fertilizer was applied. At 6 WAS, LACRIWHIT-4 produced larger leaf area than LACRIWHIT-5 and LACRIWHIT-1 when fertilizer was applied. Application of NPK alone produced larger leaf area in all the varieties but at par with combined application of NPK and FYM in LACRIWHIT-4 and LACRIWHIT-1. This was followed by application of FYM alone except in LACRIWHIT-5 and LACRIWHIT-1 when it was similar to unfertilized plots (Table 14).

4.2.5 Leaf area index (LAI)

Effects of sowing method and fertilizer on LAI of wheat varieties in 2014/2015 and 2015/2016 at Samaru and Kadawa is shown in Table 15. Varieties significantly differed in LAI only in 2014/2015 at both Samaru and Kadawa. LACRIWHIT-4 had the highest LAI and was at par with LACRIWHIT-1

Table 14: Variety and fertilizer interaction on leaf area plant^{-1} at 3 and 6 WAS in 2014/2015 dry season at Samaru and Kadawa

	Variety		
Treatment	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Fertilizer			
		Samaru 3 WAS	
Control	10.22ef	10.82e	8.41f
NPK (120: 60:60 kg ha^{-1})	29.28b	40.94a	22.33cd
FYM (10 t ha^{-1})	18.69d	27.81bc	15.50de
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	27.28bc	37.38a	19.84d
SE± 3.431			
		6 WAS	
Control	44.16d	28.48d	29.31d
NPK (120: 60:60 kg ha^{-1})	121.75a	125.10a	92.95b
FYM (10 t ha^{-1})	78.82bc	70.35c	69.22c
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	117.80a	124.30a	83.81bc
SE± 8.735			
		Kadawa 3 WAS	
Control	26.90e	27.92e	29.96e
NPK (120: 60:60 kg ha^{-1})	91.95a	57.29c	99.22a
FYM (10 t ha^{-1})	46.02cd	42.06d	52.42cd
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	74.72b	52.74cd	97.04a
SE± 5.964			
		6 WAS	
Control	72.07e	78.80e	58.20e
NPK (120: 60:60 kg ha^{-1})	121.87c	280.27a	127.17c
FYM (10 t ha^{-1})	84.17de	179.47b	84.77de
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	115.30cd	269.32a	118.40c
SE± 16.302			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

at 6 WAS at Samaru. At 9 WAS at Samaru, LACRIWHIT-1 and 5 were similar and recorded larger LAI than LACRIWHIT-4. At 3 WAS in 2014/2015 at Kadawa, LACRIWHIT-5 had the highest LAI which followed by LACRIWHIT-1 then LACRIWHIT-4. At 6 and 9 WAS, LACRIWHIT-4 followed by LACRIWHIT-1 and 5 which were similar, LACRIWHIT-5 excelled LACRIWHIT-1at 9 WAS.

Effect of sowing method was significant only at 9 WAS at Kadawa in 2015/2016 season with drilling having higher values. Application of NPK alone consistently recorded the highest LAI at all sampling periods except at 9 WAS at Kadawa in 2015/2016 season

Table 15: Leaf area index of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	Samaru						Kadawa					
	2014/2015			2015/2016			2014/2015			2015/2016		
Treatment	3WAS	6WAS	9WAS	3WAS	6WAS	9WAS	3WAS	6WAS	9WAS	3WAS	6WAS	9WAS
Variety (V)												
LACRIWHIT-1	0.50b	2.15a	4.89a	0.33	1.41	2.60	1.42b	2.32b	2.77c	0.65	2.30	4.80
LACRIWHIT-4	0.77a	2.23a	2.78b	0.34	1.67	2.91	1.17c	5.25a	4.74a	0.63	2.71	5.97
LACRIWHIT-5	0.38b	1.57b	4.74a	0.42	1.81	2.90	1.70a	2.37b	3.25b	0.63	2.93	6.27
SE±	0.049	0.136	0.290	0.046	0.158	0.329	0.073	0.162	0.134	0.069	0.328	0.537
Sowing Method (S)												
Broadcast	0.50	1.91	4.57	0.31	1.47	2.64	1.18	3.16	3.56	0.57	2.46	5.03b
Drill	0.60	2.05	4.37	0.42	1.80	2.96	1.38	3.47	3.62	0.70	2.83	6.33a
SE±	0.040	0.111	0.237	0.037	0.129	0.268	0.059	0.132	0.110	0.057	0.267	0.438
Fertilizer (F)												
Control	0.23c	0.77d	1.73d	0.07c	0.41d	1.06d	0.62d	1.51d	1.91d	0.31c	1.07c	3.92b
NPK (120: 60:60 kg ha^{-1})	0.81a	2.98a	7.52a	0.72a	3.59a	4.60a	2.22a	4.89a	5.00a	1.07a	4.89a	7.24a
FYM (10 t ha^{-1})	0.50b	1.71c	3.41c	0.15c	0.95c	2.20c	1.10c	2.77c	3.18c	0.41c	1.94bc	5.80a
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	0.65b	2.47b	5.21b	0.49b	1.58b	3.36b	1.77b	4.08b	4.27b	0.76b	2.70b	5.75a
SE±	0.057	0.157	0.335	0.053	0.183	0.379	0.084	0.187	0.155	0.080	0.378	0.620
Interaction												
Vx S	NS	NS	NS	**	**	*	NS	NS	NS	*	*	NS
V x F	NS	NS	NS	NS	NS	NS	*	**	*	NS	NS	NS
S x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

where it was at par with all other fertilizer treatments. This was consistently followed by combined application of NPK and FYM and the application of FYM alone except at 3WAS at Samaru and at 3 and 6 WAS at Kadawa in 2015/2016 season where FYM alone was similar to the control treatment.

Interaction was significant between variety and sowing method on LAI at all sampling period at Samaru and Kadawa in 2015/2016 except at 9 WAS at Kadawa (Table 16) and between variety and fertilizer throughout at Kadawa in 2014/2015 season (Table 17).

Table 16 shows interaction between variety and sowing method at Samaru (3, 6 and 9 WAS) and at Kadawa (3 and 9 WAS) in 2015/2016. At Samaru, (3 WAS) LACRIWHIT-5 produced highest LAI when drilled that was followed by the remaining variety x sowing method interactions. At 6 WAS, when drill sowing was adopted, LACRIWHIT-5 recorded the highest LAI followed by broadcasted LACRIWHIT-4,

Table 16: Interaction between variety and sowing method on leaf area index at 3, 6 and 9 WAS in Samaru at 3 and 6 WAS in Kadawa during 2015/2016 dry season

Treatment		**Variety**	
	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Sowing Method			
		Samaru 3 WAS	
Broadcast	0.36b	0.37b	0.20b
Drill	0.31b	0.31b	0.62a
SE± 0.091			
		6 WAS	
Broadcast	1.47bc	1.84b	1.08c
Drill	1.36bc	1.56bc	2.53a
SE± 0.316			
		9 WAS	
Broadcast	2.87ab	3.10ab	1.96b
Drill	2.33b	2.72ab	3.84a
SE± 0.657			
		Kadawa 3 WAS	
Broadcast	0.43b	0.58b	0.71ab
Drill	0.86a	0.68ab	0.56ab
SE± 0.139			
		9 WAS	
Broadcast	1.38b	2.91a	3.09a
Drill	3.22a	2.51ab	2.77a
SE± 0.655			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Table 17: Interaction between variety and fertilizer on leaf area index at 3 and 6 and 9 WAS in 2014/2015 dry season at Kadawa

	Variety		
Treatment	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Fertilizer		**3 WAS**	
Control	0.57f	0.61ef	0.68def
NPK (120: 60:60 kg ha^{-1})	2.37a	1.68b	2.62a
FYM (10 t ha^{-1})	1.00cde	1.03cd	1.26c
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	1.73b	1.35bc	2.23a
SE± 0.206			
		6 WAS	
Control	1.53g	1.67g	1.34g
NPK (120: 60:60 kg ha^{-1})	3.16d	8.18a	3.35d
FYM (10 t ha^{-1})	1.83fg	4.42c	2.05efg
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	2.75de	6.73b	2.75def
SE± 0.457			
		9 WAS	
Control	1.52h	2.33fg	1.88gh
NPK (120: 60:60 kg ha^{-1})	3.87cd	6.59a	4.51c
FYM (10 t ha^{-1})	2.39fg	4.39c	2.76ef
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	3.30de	5.65b	3.85cd
SE± 0.380			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

which statistically at par with all combinations except when LACRIWHIT-5 was broadcasted.

At 9 WAS (Samaru), drill planted LACRIWHIT-5 produced highest LAI but par with LACRIWHIT-4 under both sowing methods and broadcasted. At Kadawa, (3 WAS) drilled LACRIWHIT-1 recorded highest LAI but at par with drilled LACRIWHIT-4 and LACRIWHIT-5 , which were in turn similar to broadcasted LACRIWHIT-5. All varieties have same LAI under broadcasting method. At 9 WAS, all varieties produced statistically similar LAI irrespective of sowing method used except under LACRIWHIT-1 under broadcasting which is statistically having lower LAI though at par with LACRIWHIT-4 under drilling (Table 16). At 3, 6 and 9 WAS in Kadaw, all varieties produced statistically similar LAI under control and FYM, while LACRIWHIT-1 and 4 had statistically same LAI though LACRIWHIT-5 had superior

LAI when combined NPK and FYM were applied. Under NPK application, similar but statistically higher LAI was recorded by LACRIWHIT-1 and 5 which were superior to LACRIWHIT-4 (Table 17).

At 6 WAS, LACRIWHIT-4 fertilized with NPK alone surpassed all other fertilizer x variety combination and was significantly followed by LACRIWHIT-4 supplied with combined NPK and FYM. This was followed by LACRIWHIT-4 with FYM alone then followed by LACRIWHIT-5 and LACRIWHIT-1 fertilized with NPK alone but similar to when fertilized with combined with FYM. Regardless of the variety used, the control produced least LAI (Table 17). Similar trend was observed at 9 WAS at Kadawa in 2014/2015 dry season.

4.2.6 Number of tiller meter^{-2}

The number of tiller meter^{-2}of wheat varieties as influenced by sowing method and fertilizer is presented in Table 18. Varietal effect was significant on tillers meter^{-2} only at Samaru in 2014/2015 season. Variety LACRIWHIT-5 significantly recorded highest tillers m^{-2} than LACRIWHIT-1 and LACRIWHIT-4 which were at par. Sowing method was significant only at Kadawa in both seasons and the mean when drill sowing produced higher tiller m^{-2} than broadcast.

Fertilizer application had significant effect on number tiller meter^{-2} throughout the study. Application of NPK alone produced higher tiller number which was at par with combined NPK and FYM throughout study period except 2015/2016 at Samaru location where NPK alone produced statistically higher tiller m^{-2} than all applied fertilizers. At other periods, application of FYM alone and in combination with NPK recorded similar and higher tiller number than the zero fertilizer treatment. Significant variety and sowing method interactions on this parameter at Samaru in 2014/2015 and the combined mean at both locations were observed (Table 19).

Table 18: Number of tiller m^{-2} of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

Treatment	Number of tiller m^{-2}					
	Samaru			Kadawa		
	2014/2015	2015/2016	combined	2014/2015	2015/2016	combined
Variety (V)						
LACRIWHIT-1	665.07	631.78b	648.42	666.07	735.74	700.91
LACRIWHIT-4	685.20	658.94b	672.07	633.07	723.49	693.28
LACRIWHIT-5	670.67	802.61a	736.64	729.50	796.33	762.92
SE±	30.784	49.470	35.234	39.970	46.632	27.689
Sowing Method (S)						
Broadcast	651.27	738.30	694.78	630.33b	683.81b	657.02b
Drill	696.02	657.26	676.64	742.20a	819.90a	781.05a
SE±	25.135	40.392	35.234	32.635	38.074	22.608
Fertilizer (F)						
Control	495.07b	364.96c	430.01c	546.76c	589.16c	567.96c
NPK (120: 60:60 kg ha^{-1})	856.00a	1133.63a	994.81a	801.16a	885.96a	843.56a
FYM (10 t ha^{-1})	586.31b	646.89b	616.60b	657.73bc	718.63bc	688.18b
NPK (60 :30 :30 kg ha^{-1})+FYM (5 t ha^{-1})	757.20a	645.63b	701.41b	739.20ab	813.68ab	766.44ab
SE±	35.547	57.124	40.684	46.153	53.845	31.972
Interaction						
Vx S	NS	*	*	NS	NS	*
V x F	NS	NS	NS	NS	NS	NS
S x F	NS	NS	NS	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

In 2015/2016 at Samaru, LACRIWHIT-4 and LACRIWHIT-5 responded similarly to both sowing methods. Drilled LACRIWHIT-1 had similar tillers to broadcasted LACRIWHIT-4 and drilled LACRIWHIT-5. In the combined at Samaru, statistically similar tillers were produced in all the varieties when drill sowing was adopted. LACRIWHIT-4 and 5 had similar response to both sowing methods. At Kadawa in the combined, LACRIWHIT-1 and 4 recorded similar tiller number when drill sowing was adopted. On the other hand, LACRIWHIT-4 and 5 recorded similar tillers when broadcasted. LACRIWHIT-4 produced similar number of tillers at both sowing methods (Table 19).

4.2.7 Crop dry matter (g m^{-2})

Table 20 shows the effects of treatments on shoot dry matter in 2014/2015 and 2015/2016 at Samaru. Varietal variations were significant on dry matter production except at 3, 9 and 12 WAS in 2015-16 season. At other periods LACRIWHIT-4 excelled. LACRIWHIT-4 produced the heaviest dry matter but was at par with LACRIWHIT-1 at 3, 6 and 12 WAS and LACRIWHIT-5 at 3 WAS in 2014/2015

Table 19: Variety and sowing method interaction on tillers m^{-2} at Samaru in 2015/2016 dry season and the mean at Kadawa

		Variety	
Treatment	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Sowing Method		**Samaru 2015/2016**	
Broadcast	458.89d	828.56ab	927.44a
Drill	804.67ab	489.33cd	677.78bc
SE± 98.941			
		Samaru mean	
Broadcast	553.94c	733.51ab	796.89a
Drill	742.90ab	610.63bc	676.39abc
SE± 70.467			
		Kadawa mean	
Broadcast	588.31d	681.34cd	701.41c
Drill	813.51ab	705.22bc	824.43a
SE± 55.378			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Table 20: Crop dry matter (g m^{-2}) of wheat varieties as influenced by sowing method and fertilizer application at Samaru in 2014-2015 and 2015/2016 dry season

	Crop dry matter (g m^{-2})							
	2014/2015				2015/2016			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Variety (V)								
LACRIWHIT-1	32.58b	147.01a	292.33b	778.31a	28.43	169.00a	417.45	681.51
LACRIWHIT-4	34.55ab	153.34a	420.77a	719.81a	25.52	132.39b	322.25	639.58
LACRIWHIT-5	37.47a	100.86b	281.75b	601.93b	24.08	136.71ab	343.60	602.47
SE±	1.067	5.548	18.852	27.190	4.899	12.119	32.204	42.388
Sowing Method (S)								
Broadcast	33.24b	124.25b	315.59	663.97b	25.31	116.35b	311.20b	549.93b
Drill	36.50a	143.23a	347.64	736.07a	26.71	175.72a	411.00a	732.43a
SE±	0.871	4.530	15.393	22.201	1.281	9.895	26.294	34.610
Fertilizer (F)								
Control	14.55d	66.04c	206.06c	357.87c	18.36c	43.20d	139.64d	245.67d
NPK (120: 60:60 kg ha^{-1})	48.32a	174.59a	433.14a	866.72a	38.29a	249.13a	600.28a	1038.60a
FYM (10 t ha^{-1})	34.91c	132.56b	305.71b	714.73b	24.64b	106.42c	282.56c	462.40c
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	41.69b	161.78a	381.54a	860.76a	22.8bc	185.38b	421.92b	818.07b
SE±	1.232	6.406	21.768	31.397	1.812	13.994	37.186	48.946
Interaction								
Vx S	NS	NS	NS	NS	*	NS	NS	NS
V x F	NS	NS	**	NS	**	NS	NS	NS
S x F	NS	NS	NS	NS	NS	**	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing,
**= significant at 1% level of probability. NS = Not significant

season. At 6 WAS in 2015/2016 season, LACRIWHIT-1 produced heavier dry matter than LACRIWHIT-4 and was similar to LACRIWHIT-5. Sowing method significantly affected dry matter production at 3, 6 and 12 WAS in 2014/2015 and 6, 9 and 12 WAS in 2015/2016 season respectively. The drill sown wheat recorded heavier shoot dry matter than broadcast all through.

Application of NPK alone significantly produced heaviest dry matter throughout the sampling periods except at 6, 9 and 12 WAS in 2014/2015 season when it was at par with the combined application of NPK and FYM. This was followed by FYM alone then the control. There was significant interaction between variety and fertilizer (9 WAS) in 2014/2015 and (3 WAS) 2015/2016 (Table 21), between variety and sowing method at (3 WAS) in 2015/2016 (Table 22) and between sowing method and fertilizer at 6 WAS in 2015/2016 (Table 23).

At 9 WAS in 2014/2015, when either NPK alone or combined with FYM was applied, LACRIWHIT-4 significantly produced heavier dry matter than all other variety x fertilizer combinations. This was followed by LACRIWHIT-4 with FYM alone which was at par with LACRIWHIT-5 fertilizer with NPK alone and all fertilized

Table 21: Variety and fertilizer interaction on crop dry matter (g m^{-2}) at 9 and 3 WAS at Samaru in 2014/2015 and 2015/2016 dry season

	Variety		
Treatment	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Fertilizer		**2014/2015 9 WAS**	
Control	205.43de	172.02e	240.73cde
NPK (120: 60:60 kg ha^{-1})	338.53bc	569.67a	391.23b
FYM (10 t ha^{-1})	299.67bcd	375.82b	241.63cde
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	325.67bc	565.57a	253.46cde
SE± 37.704			
		2015/2016 3 WAS	
Control	22.27cde	15.07e	17.73cde
NPK (120: 60:60 kg ha^{-1})	38.67a	37.07a	39.13a
FYM (10 t ha^{-1})	26.13bc	33.13ab	14.67^{e}
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	26.67bc	16.80de	24.80bcd
SE± 4.438			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Table 22: Variety and sowing method interaction on crop dry mater (g m^{-2}) at 3 WAS Samaru in 2015/2016 dry season

	Variety		
Treatment	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Sowing Method			
Broadcast	29.77a	26.43a	19.73b
Drill	27.10a	24.40ab	28.43a
SE± 3.138			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Table 23: Sowing method and fertilizer interaction on crop dry matter (g m^{-2}) at 6 WAS Samaru in 2015/2016 dry season

	Sowing Method	
Treatment	Broadcast	Drill
Fertilizer		
Control	40.58c	45.82c
NPK (120: 60:60 kg ha^{-1})	222.22a	276.04a
FYM (10 t ha^{-1})	91.78bc	121.07b
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	110.80b	259.93a
SE± 27.988		

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

LACRIWHIT-1. Least dry matter was from zero fertilized plots which were similar to LACRIWHIT-5 fertilized with FYM alone or combined with NPK (Table 21). At 3 WAS in 2015/2016, similar response was observed among varieties when NPK alone was applied and when no fertilizer was applied,. Similar response to FYM alone and combined with NPK was recorded on dry matter in LACRIWHIT-1 and 5 (Table 21). Interaction between variety and sowing method on dry matter at 3 WAS in 2015/2016 is shown in Table 22. Similar dry matter was recorded when drill sowing was employed to all the varieties and was at par with LACRIWHIT-1 and 4 under broadcast. In Table 23, when drill sowing was adopted, combined application of NPK and FYM produced heavier dry matter than broadcast. There was no difference between sowing methods under other fertilizer levels.

The influence of sowing method and fertilizer on dry matter production of wheat varieties in 2014/2015 and 2015/2016 at Kadawa is shown in Table 24. Varietal effect

Table 24: Crop dry matter (g m^{-2}) of wheat varieties as influenced by sowing method and fertilizer application at Kadawa in 2014/2015 and 2015/2016 dry season

	Crop dry matter (g m^{-2})							
	2014/2015				2015/2016			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Variety (V)								
LACRIWHIT-1	133.44a	403.91a	871.28a	1342.2ab	67.25	225.63	586.34	806.74
LACRIWHIT-4	106.92b	310.96b	721.23b	1196.1b	70.70	203.78	548.56	824.91
LACRIWHIT-5	108.76b	310.95b	847.7ab	1510.5a	78.42	209.85	555.14	757.11
SE±	6.170	21.284	46.282	93.204	6.376	22.509	35.657	47.459
Sowing Method (S)								
Broadcast	109.19b	328.82	766.53	1331.0	60.80b	154.14b	469.12b	663.69b
Drill	123.56a	355.06	860.27	1368.2	83.44a	272.03a	657.58a	928.81a
SE±	5.038	17.378	37.789	76.101	5.206	18.379	29.114	38.750
Fertilizer (F)								
Control	58.42d	161.18c	410.15c	768.9c	42.04c	123.71c	242.47c	596.58b
NPK (120: 60:60 kg ha^{-1})	157.78a	457.36a	1038.8a	1774.3a	100.56a	344.20a	625.46ab	1007.31a
FYM (10 t ha^{-1})	113.28c	412.96a	865.24b	1262.0b	64.38b	151.31c	516.94bc	675.96b
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	136.01b	336.26b	939.4ab	1593.3a	81.51ab	233.12b	686.52a	905.17a
SE±	7.124	24.576	53.442	107.623	7.362	25.991	41.174	54.801
Interaction								
Vx S	NS	NS	NS	NS	NS	NS	NS	NS
V x F	NS	NS	NS	NS	NS	NS	NS	NS
S x F	NS	NS	NS	NS	NS	**	NS	*
V x S x F	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

was significant only in 2014/2015 season when LACRIWHIT-1 produced heaviest dry matter at 3 and 6 WAS. The same variety was at par with LACRIWHIT-5 at 9 and 12 WAS. Drill sowing recorded significantly heavier dry matter throughout sampling periods except at 6, 9 and 12 WAS in 2014/2015 season.

Fertilizer application significantly affected dry matter production. Application of NPK alone consistently produced heaviest dry matter and was at par with combined application of NPK and FYM at 9 and 12 WAS and 3, 9 and 12 WAS in 2014/2015 and 2015/2016 seasons respectively. The control produced least dry matter throughout the study. Interaction was significant on this parameter between sowing method and fertilizer at 6 and 12 WAS in 2015/2016 season (Table 25). At 6 WAS, under broadcasting all applied fertilizer are statistically similar while under drilling, control treatment and FYM produced similar but statistically the least crop dry matter.

Table 25: Interaction between sowing method and fertilizer on crop dry matter ($g\ m^{-2}$) at Kadawa in 2015/2016 dry season

Treatment	**Sowing Method**	
	Broadcast	Drill
Fertilizer	**6 WAS**	
Control	123.42c	124.00c
NPK (120: 60:60 kg ha^{-1})	201.87bc	486.53a
FYM (10 t ha^{-1})	117.82c	184.80c
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	173.44c	292.80b
SE± 51.982		
	12 WAS	
Control	510.00c	683.1bc
NPK (120: 60:60 kg ha^{-1})	787.00b	1227.6a
FYM (10 t ha^{-1})	659.90bc	692.0bc
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	697.80bc	1112.5a
SE± 94.294		

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

At 12 WAS application of either NPK alone or combination with FYM and drill sowing produced similar and heavier dry matter than any other fertilizer x sowing method combination. Similar response was observed in the control, FYM alone and combined with NPK under broadcast sowing.

4.2.8 Crop growth rate (g m^{-2} wk^{-1})

Table 26 presents treatment main and interaction effect on Crop growth rate in 2014/2015 and 2015/2016 at Samaru and Kadawa. Varietal effect was significant on wheat growth rate only at Samaru and between 3 and 6 WAS at Kadawa in 2014/2015 season. At 3-6 and 6-9 WAS at Samaru, LACRIWHIT-4 had the highest CGR which was similar to LACRIWHIT-1 and LACRIWHIT-5 respectively. From 9-12 WAS at Samaru and 3-6 WAS at Kadawa, LACRIWHIT-1 recorded the higher than LACRIWHIT-4 and LACRIWHIT-5 varieties which were at par.

Sowing method was significant on CGR except in Samaru at 6-9, 9-12 WAS (2014/2015) and 6-9 WAS (2015/2016) and 3-6 WAS in 2014/2015 at Kadawa. Drill sowing recorded higher CGR throughout except in 6-9 WAS at Kadawa in 2014/2015 dry season broadcast excelled.

Application of NPK alone higher CGR throughout sampling periods except at Samaru between 3-6, 6-9 WAS (2014/2015) and 9-12 WAS in (2015/2016) and at Kadawa 3-6, 9-12 WAS in (2015/2016) when it was at par with combine NPK and FYM. It was also similar to all fertilized plots in 2014/2015 season at 9-12 WAS (Samaru) and 6-9 WAS (Kadawa). The control produced least CGR throughout the study. Significant interaction was observed between variety and fertilizer at 6-9 and 9-12 WAS at Samaru in 2014/2015 and between sowing method and fertilizer at 3-6 at Samaru in 2015/2016 and also at 3-6 and 9-12 WAS (Kadawa) in 2015/2016 (Tables 27 and 28).

Table 27 presents interaction between variety and fertilizer at 6-9 and 9-12 WAS at Samaru in 2014/2015. LACRIWHIT-1 produced statistically similar CGR irrespective of fertilizer applied at 6-9 WAS. Under FYM application all varieties produced statistically similar CGR; there was also no significant difference between LACRIWHIT-1 and 5 under NPK + FYM application. Maximum CGR was recorded by

Table 26: Crop growth rate (g m^{-2} wk^{-1}) of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	Crop growth rate (g m^{-2} wk^{-1})											
	Samaru						Kadawa					
	2014/2015			2015/2016			2014/2015			2015/2016		
Treatment	3-6 WAS	6-9 WAS	9-12 WAS	3-6 WAS	6-9 WAS	9-12 WAS	3-6 WAS	6-9 WAS	9-12 WAS	3-6 WAS	6-9 WAS	9-12 WAS
Variety (V)												
LACRIWHIT-1	38.14a	48.44b	161.99a	46.86	82.82	88.02	90.16a	155.79	156.98	203.22	511.13	611.29
LACRIWHIT-4	39.60a	89.14a	99.68b	35.63	63.29	105.78	68.01b	136.76	158.28	180.21	480.63	642.06
LACRIWHIT-5	21.13b	60.30a	106.73b	37.54	68.96	86.29	67.40b	178.92	220.95	183.71	485.19	572.06
SE±	1.912	5.989	9.524	4.094	9.502	9.265	6.825	15.901	32.243	21.616	32.415	40.830
Sowing Method (S)												
Broadcast	30.34b	63.78	116.13	30.35b	64.95	79.58b	73.21	177.15a	156.91	133.87b	417.74b	507.32b
Drill	35.58a	68.14	129.48	49.67a	78.43	107.14a	77.17	137.66b	200.56	244.22a	566.90a	709.62a
SE±	1.561	4.890	7.776	3.343	7.758	7.564	5.613	12.983	26.326	17.649	26.467	33.338
Fertilizer (F)												
Control	17.16c	46.67c	50.60b	8.28d	32.15c	35.34b	34.25c	82.99b	119.58b	107.70c	383.23c	455.09b
NPK (120: 60:60 kg ha^{-1})	42.09a	86.19a	144.53a	70.28a	117.05a	146.11a	99.86a	193.81a	245.18a	310.68a	510.72ab	798.83a
FYM (10 t ha^{-1})	32.55b	57.72bc	136.34a	27.26c	58.71bc	59.95b	74.32b	176.33a	132.24b	129.85c	466.51bc	503.64b
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	40.03a	73.25ab	159.74a	54.21b	78.85b	132.05a	92.32ab	175.49a	217.94ab	205.95b	608.81a	676.33a
SE±	2.208	6.915	10.997	4.727	10.972	10.698	57.938	18.361	37.231	24.960	37.429	47.147
Interaction												
Vx S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
V x F	NS	**	*	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x F	NS	NS	NS	**	NS	NS	NS	NS	NS	**	NS	*
V x S x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

Table 27:Interaction between variety and fertilizer on crop growth rate (g m^{-2} wk^{-1}) at 6-9 and 9-12 WAS at Samaru in 2014/2015 dry season

	Variety		
Treatment	LACRIWHIT -1	LACRIWHIT-4	LACRIWHIT-5
Fertilizer		**6-9 WAS**	
Control	41.39e	33.84e	64,79f
NPK (120: 60:60 kg ha^{-1})	46.64de	123.87a	88.04bc
FYM (10 t ha^{-1})	51.20de	77.79cd	44.16de
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	54.51cde	121,05ab	44.20de
SE± 16.139			
		9-12 WAS	
Control	61.88def	55.77ef	34.16f
NPK (120: 60:60 kg ha^{-1})	199.09a	111.46cd	123.03bc
FYM (10 t ha^{-1})	171.41ab	135.58bc	102.02cde
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	215.61a	95cde	167.69ab
SE± 26.937			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Table 28: Interaction between sowing method and fertilizer on crop growth rate (g m^{-2} wk^{-1}) at 3-6 WAS at Samaru and Kadawa in 2015/2016 dry season

	Sowing method	
Treatment	Broadcast	Drill
Fertilizer	**Samaru**	
	3-6 WAS	
Control	8.47c	8.09c
NPK (120: 60:60 kg ha^{-1})	61.13a	79.44a
FYM (10 t ha^{-1})	22.50bc	32.02b
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	29.28b	79.13a
SE± 9.454		
	Kadawa	
	3-6 WAS	
Control	110.65c	108.74c
NPK (120: 60:60 kg ha^{-1})	171.04bc	450.12a
FYM (10 t ha^{-1})	100.03c	159.67bc
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	153.56c	258.34b
SE± 49.920		
	9-12 WAS	
Control	381.06c	529.12bc
NPK (120: 60:60 kg ha^{-1})	625.02b	972.63a
FYM (10 t ha^{-1})	507.65bc	499.63bc
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	515.56bc	837.10a
SE± 66.667		

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

LACRIWHIT-4 with the application of NPK alone, though this was statistically at par with LACRIWHIT-4 with the application of NPK+FYM. At 9-12 WAS, LACRIWHIT-1 and 4 produced similar CGR when fertilizer was applied. All the varieties produced statistically similar CGR when no fertilizer was applied. Highest CGR was observed under fertilized LACRIWHIT-1 which was at par with LACRIWHIT-5 fertilized with combined NPK and FYM (Table 27).

Interaction between sowing method and fertilizer at 3-6 at Samaru and at Kadawa at 3-6 and 9-12 WAS in 2015/2016 is shown in Table 28. At Samaru, irrespective of the control, NPK and FYM alone, sowing method produced statistically similar CGR, while under the application of NPK+FYM, drill sowing method produced statistically higher than broadcasting. At 3-6 WAS in Kadawa, irrespective of fertilizer applied, similar CGR was recorded when broadcasting was employed. Under the control and FYM alone, statistically similar CGR was observed in both sowing methods. Highest CGR was recorded when NPK alone was applied to drill sown wheat. Similar CGR was observed in all the fertilized plots under broadcast sowing at 9-12 WAS at Kadawa. Also, statistically similar CGR was observed in both sowing methods under the control and FYM alone. Maximum CGR was recorded by drill supplied with NPK alone and combined with FYM.

4.2.9 Relative growth rate (g g^{-1} wk^{-1})

Relative Growth Rate (RGR) was significant on variety throughout observation periods at Samaru except at 3-6 and 6-9 WAS in 2015/2016 and only at 9-12 WAS at Kadawa (Table 29). LACRIWHIT-5 significantly produced higher RGR at 6-9 and 9-12 WAS at Samaru in 2014/2015 and 2015/2016 season, respectively, but was at par with LACRIWHIT-4 at 6-9 WAS at Samaru in 2014/2015 and at 9-12 at Samaru in 2015/2016. Sowing method was significant only at Kadawa at 6-9 WAS in 2014/2015

Table 29: Relative growth rate (g g^{-1} wk^{-1}) of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	Relative growth rate (g g^{-1} wk^{-1})											
	Samaru						**Kadawa**					
	2014/2015			2015/2016			2014/2015			2015/2016		
Treatment	3-6 WAS	6-9 WAS	9-12 WAS	3-6 WAS	6-9 WAS	9-12 WAS	3-6 WAS	6-9 WAS	9-12 WAS	3-6 WAS	6-9 WAS	9-12 WAS
Variety (V)												
LACRIWHIT-1	0.52a	0.23b	0.32a	0.52	0.32	0.17b	0.37	0.26b	0.15	0.35	0.37	0.11
LACRIWHIT-4	0.51a	0.33a	0.19c	0.51	0.14	0.23a	0.36	0.27b	0.17	0.34	0.37	0.14
LACRIWHIT-5	0.33b	0.35a	0.26b	0.55	0.33	0.20ab	0.35	0.36a	0.20	0.32	0.36	0.10
SE±	0.020	0.021	0.022	0.042	0.027	0.019	0.026	0.025	0.025	0.030	0.030	0.018
Sowing Method (S)												
Broadcast	0.44	0.31	0.26	0.48	0.34	0.19	0.36	0.33a	0.14	0.30b	0.39	0.12
Drill	0.46	0.29	0.26	0.57	0.31	0.21	0.36	0.26b	0.20	0.37a	0.35	0.11
SE±	0.016	0.017	0.018	0.035	0.022	0.015	0.021	0.021	0.021	0.025	0.024	0.015
Fertilizer (F)												
Control	0.51a	0.38a	0.19b	0.31c	0.40a	0.19ab	0.38	0.33	0.21	0.34	0.44a	0.11ab
NPK (120: 60:60 kg ha^{-1})	0.41b	0.30b	0.25ab	0.61ab	0.30b	0.20ab	0.35	0.26	0.18	0.37	0.24b	0.16a
FYM (10 t ha^{-1})	0.44b	0.26b	0.30a	0.50b	0.32ab	0.17b	0.36	0.31	0.13	0.30	0.41a	0.10ab
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	0.45b	0.27b	0.29a	0.67a	0.28b	0.24a	0.36	0.28	0.17	0.34	0.40a	0.09b
SE±	0.023	0.025	0.026	0.049	0.031	0.021	0.030	0.029	0.029	0.035	0.035	0.021
Interaction												
Vx S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
V x F	NS	**	*	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x F	NS	NS	NS	*	NS	NS	NS	NS	NS	*	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

Effect of fertilizer on RGR was significant at Samaru in both seasons and in Kadawa at 6-9 and 9-12 WAS in 2015/2016 season. Generally, there was no significant difference among fertilizer treatments but significantly higher than the control except at 3-6 and 6-9 at Samaru in 2014/2015 where the control was higher and at 6-9 and 9-12 WAS at Samaru in 2015/2016 where it was similar to FYM. There was significant interaction between variety and fertilizer on RGR at 6-9 and 9-12 WAS at Samaru in 2014/2015 and between sowing method and fertilizer at 3-6 WAS in 2015/2016 at both locations (Table 30 and 31).

At Samaru in 6-9 WAS, under LACRIWHITs 1-5, all applied fertilizer types produced statistically similar RGR values, which were significantly lower than RGR values under the control treatment, though under LACRIWHIT-1 the control was at par with the application of FYM alone and NPK+ FYM respectively. Under LACRIWHIT-4 however, all fertilizer treatments produced statistically similar RGR. On general note, LACRIWHIT-5 produced the highest RGR under the control treatment (Table 30). At 9-12 WAS, statistically similar response was observed in all the varieties under NPK alone and control treatment. LACRIWHIT-1-5 produced RGR fertilizer was applied. Highest RGR was observed in all fertilized LACRIWHIT-1 and LACRIWHIT-5 under FYM alone or combined with NPK (Table 30). Interaction between sowing method and fertilizer on RGR at 3 WAS at Samaru and Kadawa in 2015/2016 is shown in Table 31. At Samaru, sowing method x fertilizer produced statistically similar RGR except when NPK alone or in combination with FYM was applied to drill which produced the highest. However, drill under NPK alone was at par with all the fertilized wheat in the broadcast plots. All combinations of sowing method and applied fertilizer produced statistically similar RGR at Kadawa except the combination of NPK and drill sowing method, which produced statisticallythe highest RGR value than all other interactions.

Table 30: Interaction between variety and fertilizer on relative growth rate (g g^{-1} wk^{-1}) at 6-9 and 9-12 WAS at Samaru in 2014/2015 dry season

	Variety		
Treatment	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Fertilizer		**6-9 WAS**	
Control	0.31bc	0.30bc	0.54a
NPK (120: 60:60 kg ha^{-1})	0.18d	0.35b	0.36b
FYM (10 t ha^{-1})	0.22cd	0.32bc	0.25bcd
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	0.22cd	0.34b	0.25bcd
SE± 0.060			
		9-12 WAS	
Control	0.22cd	0.22cd	0.12d
NPK (120: 60:60 kg ha^{-1})	0.34ab	0.15d	0.25bcd
FYM (10 t ha^{-1})	0.36ab	0.24bcd	0.30abc
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	0.38a	0.14d	0.36ab
SE± 0.063			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Table 31:Interaction between sowing method and fertilizer on relative growth rate (g g^{-1} wk^{-1}) 3-6 WAS at Samaru and Kadawa in 2015/2016 dry season

	Sowing Method	
Treatment	Broadcast	Drill
Fertilizer	**Samaru**	
Control	0.37cd	0.26d
NPK (120: 60:60 kg ha^{-1})	0.56bc	0.66ab
FYM (10 t ha^{-1})	0.47bc	0.53bc
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	0.51bc	0.83a
SE± 0.098		
	Kadawa	
Fertilizer (F)	Broadcast	Drill
Control	0.35b	0.34b
NPK (120: 60:60 kg ha^{-1})	0.24b	0.49a
FYM (10 t ha^{-1})	0.26b	0.34b
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	0.35b	0.32b
SE± 0.070		

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

4.2.10 Net assimilation rate (g cm^{-2} wk^{-1})

Treatment main and interaction effects on NAR are presented in Table 32. Varietal means differed significantly throughout except 6-9 WAS at Samaru in both season and at 3-6 WAS at Kadawa 2015/2016 season. In Samaru, 2014/2015 LACRIWHIT-5 recorded statistically higher assimilation rate than LACRIWHIT-1. In 2015/2016, the reverse obtained. At Kadawa, LACRIWHIT-1 and LACRIWHIT-5 registered higher and statistically similar NAR in 2014/2015 while at 6-9 WAS in 2015/2016 LACRIWHIT-1 excelled LACRIWHIT-5 but at par with LACRIWHIT-4.

Sowing method was significant only at 6-9 WAS at Samaru in 2015/2016 and at 3-6 WAS at Kadawa in 2014/2015. Drill sown attained higher NAR than broadcast at Samaru and the reverse was obtained at Kadawa. Fertilizer effect on NAR was significant throughout the study except at 6-9 WAS at Kadawa in 2014/2015 season. The unfertilized plots statistically recorded higher NAR throughout but at par with NPK alone (at 6-9 WAS, 2015/2016 at Samaru), FYM alone (at 6-9 2014/2015 and 3-6 WAS 2015/2016 Samaru and Kadawa both seasons) and NPK+FYM (6-9 Samaru both seasons and Kadawa 6-9 WAS in 2015/2016).

Significant variety and fertilizer interactions were recorded on NAR at 3-6 WAS in 2014/2015 at Samaru as well as between variety and sowing method at 6-9 WAS at both locations. There was also significant sowing method and fertilizer interaction on NAR, 6-9 WAS at Samaru in 2015/2016 (Tables 33, 34 and 35). At 3-6 WAS, all varieties recorded statistically similar NAR at all applied fertilizer treatments except under control treatment when LACRIWHIT-5 recorded statistically higher NAR than LACRIWHIT-1 and 4 which were at par. Similarly, all fertilizer treatments produced statistically similar NAR irrespective of variety used except under LACRIWHIT-5, where the control treatment produced statistically higher NAR than all applied fertilizer

Table 32: Net assimilation rate (g cm^{-2} wk^{-1}) of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	Net assimilation rate (g cm^{-2} wk^{-1})							
	Samaru				**Kadawa**			
	2014/2015		2015/2016		2014/2015		2015/2016	
Treatment	3-6 WAS	6-9 WAS	3-6 WAS	6-9 WAS	3-6 WAS	6-9 WAS	3-6 WAS	6-9 WAS
Variety (V)								
LACRIWHIT-1	0.005b	0.006	0.016a	0.005	0.009a	0.007a	0.062	0.023a
LACRIWHIT-4	0.008ab	0.004	0.011b	0.006	0.006b	0.003b	0.048	0.020ab
LACRIWHIT-5	0.011a	0.004	0.010b	0.005	0.010a	0.009a	0.048	0.016b
SE±	0.0012	0.0005	0.0015	0.0005	0.0009	0.0011	0.0057	0.0022
Sowing Method (S)								
Broadcast	0.008	0.005	0.013	0.004b	0.010a	0.006	0.049	0.019
Drill	0.008	0.005	0.012	0.006a	0.007b	0.006	0.056	0.021
SE±	0.0010	0.0013	0.0013	0.0005	0.00071	0.00999	0.0046	0.0018
Fertilizer (F)								
Control	0.015a	0.005a	0.017a	0.005ab	0.009ab	0.008	0.076a	0.024a
NPK (120: 60:60 kg ha^{-1})	0.006b	0.003b	0.008c	0.005ab	0.006b	0.006	0.025c	0.016b
FYM (10 t ha^{-1})	0.006b	0.006a	0.014ab	0.004b	0.011a	0.005	0.061ab	0.019ab
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	0.005b	0.005ab	0.010bc	0.006a	0.007b	0.007	0.049b	0.020ab
SE±	0.0014	0.0006	0.0018	0.0006	0.0011	0.0013	0.0066	0.0025
Interaction								
Vx S	NS	NS	NS	*	NS	NS	NS	*
V x F	**	NS	NS	NS	NS	NS	NS	NS
S x F	NS	NS	NS	*	NS	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing,
**= significant at 1% level of probability. NS = Not significant

Table 33: Interaction between variety and fertilizer on Net Assimilation Rate (g cm^{-2} wk^{-1}) at 3-6 WAS at Samaru in 2014/2015 dry season

Treatment		**Variety**	
Fertilizer)	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Control	0.009bc	0.011b	0.025a
NPK (120: 60:60 kg ha^{-1})	0.003c	0.006bc	0.008bc
FYM (10 t ha^{-1})	0.005bc	0.008bc	0.006bc
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	0.004c	0.007bc	0.005bc
SE± 0.0033			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Table 34: Interaction between variety and sowing method on Net Assimilation Rate (g cm^{-2}wk^{-1}) at 6-9 WAS at Samaru and Kadawa in 2015/2016 dry season

		Variety	
Treatment	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Sowing Method		**Samaru**	
Broadcast	0.004b	0.004b	0.005b
Drill	0.006ab	0.008a	0.004b
SE± 0.001			
		Kadawa	
Broadcast	0.026a	0.015b	0.016b
Drill	0.021ab	0.026a	0.015b
SE± 0.004			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Table 35: Interaction between sowing method and fertilizer on Net Assimilation Rate (g cm^{-2} wk^{-1}) at 6-9 WAS at Samaru in 2015/2016 dry season

Treatment	**Sowing Method**	
Fertilizer	Broadcast	Drill
Control	0.004cd	0.008a
NPK (120: 60:60 kg ha^{-1})	0.004cd	0.005bcd
FYM (10 t ha^{-1})	0.003d	0.005a-d
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	0.007ab	0.006abc
SE± 0.001		

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

types (Table 33). At Samaru, all varieties produced statistically similar under broadcast sowing method while with drilling, there was no significant difference between LACRIWHIT-1 and 4 as well as LACRIWHIT-1 and 5, though LACRIWHIT-4 is superior to LACRIWHIT-5. Irrespective of variety used, sowing method produced statistically similar NAR except under LACRIWHIT-4 where drilling produced significantly higher NAR than broadcasting. Similar trend was recorded in Kadawa except that LACRIWHIT-1 recorded higher NAR than LACRIWHIT-4 under broadcasting (Table 34).

At 6-9 WAS at Samaru in 2015/2016, regardless of sowing method, statistically similar NAR was recorded when fertilizer was applied. Similarlly, regardless of fertilizer applied, NAR was at par under broadcast except when combine NPK and FYM was applied. Similarly, under drill sowing NAR recorded were at par except when no fertilizer was applied which excelled (Table 35).

4.2.11 Days to 50 % heading

The effect of sowing method and fertilizer on number of days to 50 % heading of wheat varieties in 2014/2015 and 2015/2016 dry season and combined analysis at Samaru and Kadawa is presented in Table 36. Varietal variations on days to 50% heading was significant throughout the study. LACRIWHIT-1 took fewer days to 50% heading in 2015/2016 and the combined analysis at Samaru. At other periods, it was at par with LACRIWHIT-4 while LACRIWHIT-5 took the longest days throughout the study. Effect of sowing method was significant only at Samaru where drilled wheat took fewer days to 50% heading than broadcasted wheat.

Application of NPK alone and in combination with FYM resulted in earlier attainment of 50 % heading throughout the study except in 2014/2015 at Samaru where it was similar to all the fertilized plots. Though the control treatment was superior to all

Table 36: Days to 50% heading of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	Days to 50% heading					
	Samaru			Kadawa		
Treatment	2014/2015	2015/2016	combined	2014/2015	2015/2016	combined
Variety (V)						
LACRIWHIT-1	55.75b	55.83c	55.79c	58.54b	58.25b	58.40b
LACRIWHIT-4	57.38b	56.92b	57.15b	58.75b	57.75b	58.25b
LACRIWHIT-5	68.54a	69.29a	68.92a	70.83a	70.33a	70.58a
SE±	0.579	0.331	0.310	0.360	0.369	0.300
Sowing Method (S)						
Broadcast	61.25a	61.28a	61.26a	63.06	62.33	62.69
Drill	59.86b	60.08b	59.97b	62.36	61.89	62.13
SE±	0.473	0.270	0.253	0.294	0.301	0.237
Fertilizer (F)						
Control	65.22a	65.33a	65.28a	67.33a	67.72a	67.53a
NPK (120: 60:60 kg ha^{-1})	58.50b	58.89c	58.69c	59.94c	59.61c	59.78c
FYM (10 t ha^{-1})	59.61b	60.06b	59.83b	61.83b	61.50b	61.67b
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	58.89b	58.44c	58.67c	61.72b	59.61c	60.67c
SE±	0.668	0.382	0.358	0.416	0.426	0.335
Interaction						
Vx S	NS	NS	NS	NS	NS	NS
V x F	NS	NS	**	**	NS	NS
S x F	NS	NS	NS	**	NS	*
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

Table 37: Interaction between variety and fertilizer on days to 50% heading at combined in Samaru and at Kadawa in 2014/2015 dry seasons

	Variety		
Treatment	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Fertilizer		**Samaru (Combined)**	
Control	59.08d	62.33c	74.42a
NPK (120: 60:60 kg ha^{-1})	55.00f	54.42f	66.67b
FYM (10 t ha^{-1})	54.83f	57.33^{e}	67.33b
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	54.25f	54.50f	67.25b
SE± 0.620			
		Kadawa (2014/2015)	
Control	62.00d	64.67c	75.33a
NPK (120: 60:60 kg ha^{-1})	55.50g	56.17g	68.17b
FYM (10 t ha^{-1})	56.83fg	58.50ef	70.17b
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	59.83e	55.67g	69.67b
SE± 0.720			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Table 38: Interaction between sowing method and fertilizer on days to 50% heading at Kadawa in 2014/2015 and combined mean

	Sowing Method	
Treatment	Broadcast	Drill
Fertilizer	**Kadawa 2014/2015**	
Control	67.11a	67.56a
NPK (120: 60:60 kg ha^{-1})	60.00d	59.89d
FYM (10 t ha^{-1})	61.56cd	62.11bc
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	63.56b	59.89d
SE± 0.588		
	Kadawa Combined	
Control	67.44a	67.61a
NPK (120: 60:60 kg ha^{-1})	60.17cd	59.39d
FYM (10 t ha^{-1})	61.39bc	61.94b
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	61.78b	59.56d
SE± 0.473		

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

fertilized plots throughout the seasons and locations. There were significant interactions between variety and fertilizer in combined at Samaru and at Kadawa in 2014/2015 (Table 37) as well as between sowing method and fertilizer at Kadawa in 2014/2015 and the combined (Table 38).

At Samaru in the combined analysis, similar response to days to 50% flowering was observed under LACRIWHIT-1 and 5 when fertilizer was applied. On the other hand, LACRIWHIT-1 and 4 were at par when NPK alone or combined with FYM was applied. LACRIWHIT-5 under no fertilizer recorded statistically longest days to 50% heading. At Kadawa LACRIWHIT-5 recorded similar days to 50% heading when fertilizer was applied. LACRIWHIT-1 and 4 were at par when NPK alone was applied. This was similar to LACRIWHIT-1 under FYM and LACRIWHIT-4 fertilized with combined NPK and FYM. LACRIWHIT-5 took longest days to 50% heading when no fertilizer was applied (Table 37).

Table 38 shows the interaction between sowing method and fertilizer at Kadawa in 2014/2015 and the combined. At Kadawa in 2014/2015 regardless of sowing method, statistically similar days to 50% heading was observed when NPK or FYM alone was appled and when no fertilizer was applied. Longer days to 50% heading was observed in the unfertilized plots under both sowing methods. Similar trend was observed in the combined mean at Kadawa (Table 38).

4.2.12 Days to 50 % flowering

Table 39 presents the effect of sowing method and fertilizer on number of days to 50 % flowering of wheat varieties in 2014/2015 and 2015/2016 dry season and combined analysis at Samaru and Kadawa. Varieties LACRIWHIT-1 took longer days attain 50 % flowering than LACRIWHIT-1 and LACRIWHIT-4 which were at par in all years and

Table 39: Days to 50% flowering of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	Days to 50% flowering					
	Samaru			**Kadawa**		
Treatment	2014/2015	2015/2016	combined	2014/2015	2015/2016	combined
Variety (V)						
LACRIWHIT-1	57.04b	57.21b	57.13c	59.25b	59.63b	59.44b
LACRIWHIT-4	58.75b	57.83b	58.29b	59.67b	58.86b	59.27b
LACRIWHIT-5	69.83a	70.50a	70.17a	72.08a	71.29a	71.69a
SE±	0.611	0.396	0.342	0.400	0.396	0.307
Sowing Method (S)						
Broadcast	62.61a	62.33a	62.47a	64.06	63.31	63.68
Drill	61.14b	61.36b	61.25b	63.28	63.22	63.25
SE±	0.499	0.324	0.279	0.327	0.323	0.251
Fertilizer (F)						
Control	66.61a	55.39a	66.50a	68.06a	68.94a	68.50a
NPK (120:60:60kg ha^{-1})	59.61b	60.22c	59.92c	61.11c	60.44c	60.78c
FYM (10 t ha^{-1})	61.06b	61.17b	61.11b	62.83b	62.72b	62.78b
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	60.22b	59.61c	59.92c	62.27b	60.94c	61.81b
SE±	0.706	0.458	0.395	0.462	0.457	0.355
Interaction						
Vx S	NS	NS	NS	NS	NS	NS
V x F	NS	NS	*	**	NS	*
S x F	NS	NS	NS	*	NS	*
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. *= significant at 5% level of probability. NS = Not significant

Table 40: Interaction between variety and fertilizer on days to 50% flowering at Samaru in combined and at kadawa in 2014/2015 and the combine mean

	Variety		
Treatment	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Fertilizer		**Samaru Combined**	
Control	60.42d	63.33c	75.75a
NPK (120: 60:60 kg ha^{-1})	56.25e	55.67e	67.83b
FYM (10 t ha^{-1})	56.08^{e}	58.58d	68.67b
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	55.75^{e}	55.58^{e}	68.42b
SE± 0.684			
		Kadawa 2014/2015	
Control	62.67d	65.17c	76.33a
NPK (120: 60:60 kg ha^{-1})	56.17f	57.33f	69.83b
FYM (10 t ha^{-1})	57.33f	60.00e	71.17b
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	60.83de	56.17f	71.00b
SE± 0.800			
		Combined	
Control	64.50c	77.25a	63.75c
NPK (120: 60:60 kg ha^{-1})	56.92ef	69.08b	56.33f
FYM (10 t ha^{-1})	59.42d	70.33b	58.58de
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	56.25f	70.08b	59.08d
SE± 0.983			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Table 41: Interaction between sowing method and fertilizer on days to 50% flowering at Kadawa in 2014/2015 dry season and the combine mean

	Sowing Method	
Treatment	Broadcast	Drill
Fertilizer	**2014/2015**	
Control	67.78a	68.33a
NPK (120: 60:60 kg ha^{-1})	61.33cd	60.89d
FYM (10 t ha^{-1})	62.67bcd	63.00bc
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	64.44b	60.89d
SE± 0.653		
	Combined	
Control	68.11a	68.89a
NPK (120: 60:60 kg ha^{-1})	61.17c	60.39c
FYM (10 t ha^{-1})	62.61b	62.94b
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	62.83b	60.78c
SE± 0.502		

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

locations except in the combined at Samaru where LACRIWHIT-1 statistically took the least number of days to 50 % flowering.

Effect of sowing method was only significant at Samaru in both years and the combined where drilled wheat took few days to flower than broadcast.

Application of fertilizer had significant effect on attainment of days to 50% flowering. Application of NPK alone significantly took few days to flower except at Samaru in 2014/2015 and the combined and at Kadawa in 2015/2016 where it was at par with combined application of NPK and FYM while at Samaru in 2014/2015 there was no significant variation among fertilized plots. There was significant interaction between variety and fertilizer in the combined at both locations and in 2015/2016 at Kadawa (Table 40) also between sowing method and fertilizer in 2014/2015 and the combined mean at Kadawa (Table 41).

Table 40 shows interaction between variety and fertilizer on days to 50% flowering at Samaru in the combined and at Kadawa in 2014/2015 and the combined. In the combined, irrespective of fertilizer treatment used, LACRIWHIT-5 took consistently and significantly longer days to attain 50% flowering compared to LACRIWHIT-1 and 4. Similarly, LACRIWHIT-4 statistically took longer days to 50% flowering than LACRIWHIT-1 irrespective of type of fertilizer used except under NPK alone and in combination with FYM. However, LACRIWHIT-5 took statistically longer days to attain 50% flowering under the control treatment. Similar trend was recorded in 2014/2015 at Kadawa only that this time around combination of NPK and FYM resulted in longer days to 50% flowering (Table 40).

Irrespective of applied fertilizer, sowing methods produced statistically same number of days to 50% flowering at Kadawa in 2014/2015 season, except when NPK in combination when broadcasted crops took longer days to 50% flowering compared to the drilled crops. Similarly, irrespective of sowing method considered, the control treatment took longest days to 50% flowering, while the least was produced with the application of NPK alone, though this was at par with either FYM under broadcasting or combined NPK and FYM under drilling. Similar trend was recorded under the combined analysis (Table 41).

4.2.13 Days to physiological maturity

The effect of sowing method and fertilizer on days to maturity of wheat varieties in 2014/2015 and 2015/2016 dry season and the combined at Samaru and Kadawa is presented in Table 42. There was significant difference among the varieties on days to maturity. LACRIWHIT-5 significantly took longer days to maturity throughout the study. This was followed by LACRIWHIT-1 then 4 at Samaru but the reverse was observed at Kadawa. There was no significant effect of sowing method on days to maturity at both locations.

Irrespective of year or location, application of NPK alone or in combination with FYM resulted in shortest days to maturity though in 2015/2016, there was no statistical difference among all applied fertilizers. Generally the control treatment took statistically the longest days to maturity in all seasons all locations and the combined.

Interaction was significant between variety and fertilizer on days to maturity in 2014/2015, 2015/2016 and the combined at Kadawa (Table 43) and between sowing method and fertilizer at Kadawa in 2015/2016 (Table 44).

Table 43 presents interaction between variety and fertilizer on days to maturity of wheat at Kadawa in 2014/2015, 2015/2016 and the combined. At Kadawa in 2014/2015, regardless of type of fertilizer supplied, LACRIWHIT-1 and 4 statistically took same and shorter days to mature than LACRIWHIT-5, though under FYM alone, LACRIWHIT-1 took statistically shorter days to maturity than LACRIWHIT-4.

Table 42: Days to physiological maturity of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	Days to physiological maturity					
	Samaru			Kadawa		
Treatment	2014/2015	2015/2016	combined	2014/2015	2015/2016	combined
Variety (V)						
LACRIWHIT-1	94.96b	95.71b	95.33b	89.50c	87.46c	88.48c
LACRIWHIT-4	91.17b	88.25c	90.21c	91.46b	88.83b	90.15b
LACRIWHIT-5	115.50a	106.67a	111.08a	110.63a	113.79a	112.21a
SE±	1.005	1.229	0.901	0.636	0.441	0.473
Sowing Method (S)						
Broadcast	101.50	99.83	99.67	97.47	96.89	97.18
Drill	100.25	95.92	98.08	96.92	96.50	96.71
SE±	0.820	1.003	0.736	0.519	0.360	0.386
Fertilizer (F)						
Control	106.39a	107.33a	106.86a	102.39a	100.39	101.39a
NPK (120: 60:60 kg ha^{-1})	97.11c	92.33b	94.72c	94.28c	93.94c	94.11c
FYM (10 t ha^{-1})	100.72b	95.33b	98.03b	97.39b	96.00b	96.69b
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	99.28bc	92.50b	95.89bc	94.72c	96.44b	95.58bc
SE±	1.160	1.419	1.041	0.734	0.509	0.546
Interaction						
Vx S	NS	NS	NS	NS	NS	NS
V x F	NS	NS	NS	*	**	*
S x F	NS	NS	NS	NS	*	NS
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

Table 43: Interaction between variety and fertilizer on days to maturity at kadawa in 2014/2015, 2015/2016 dry season and the combine mean

	Variety		
Treatment	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Fertilizer		**2014/2015**	
Control	93.83c	94.50c	118.83a
NPK (120: 60:60 kg ha^{-1})	87.00d	89.33d	106.50b
FYM (10 t ha^{-1})	89.50d	93.50c	109.17b
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	87.67d	88.50d	108.00b
SE± 1.272			
		2015/2016	
Control	89.17e	93.00d	119.00a
NPK (120: 60:60 kg ha^{-1})	84.33g	86.83efg	110.67c
FYM (10 t ha^{-1})	87.50ef	86.33fg	114.17b
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	88.83ef	89.17e	111.33c
SE± 0.882			
		Combined	
Control	91.50de	93.75d	118.92a
NPK (120: 60:60 kg ha^{-1})	85.67g	88.08fg	108.58c
FYM (10 t ha^{-1})	88.50f	89.92ef	111.58b
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	88.25fg	88.83f	109.67bc
SE± 0.942			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Table 44: Interaction between sowing method and fertilizer on days to maturity at Kadawa in 2015/2016 dry season

	Sowing Method	
Treatment	Broadcast	Drill
Fertilizer		
Control	101.67a	99.11b
NPK (120: 60:60 kg ha^{-1})	92.78d	95.11c
FYM (10 t ha^{-1})	96.44c	95.56c
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	96.67c	96.22c
SE± 0.720		

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Table 44 presents interaction between sowing method and fertilizer at Kadawa in 2015/2016. The control treatment consistently and statistically took longer days to maturity under both broadcasting and drilling sowing methods, while NPK+ FYM resulted in the shortest days to maturity, though this was statistically at par with all applied fertilizers under drilling and with application of FYM when broadcasting was considered.

4.2.14 Effective grain filling period (days)

Table 45 presents the effect of sowing method and fertilizer on effective grain filling period of wheat varieties in 2014/2015 and 2015/2016 dry season and the combined at Samaru and Kadawa. LACRIWHIT-5 consistently recorded longer grain filling period than LACRIWHIT-4 and LACRIWHIT-1 in both seasons for all locations and the combined except in 2015/2016 and the combined at Samaru where it was at par with LACRIWHIT-1. The effect of sowing method on days to grain filling of wheat was not significant throughout the study.

The effect of fertilizer on days to grain filling of wheat was significant at Samaru and Kadawa in 2015/2016 and the combined and at Samaru. The unfertilized plots took longer days for grain filling while the fertilized plots responded similarly at Samaru. At Kadawa, combined application of NPK and FYM resulted in longer grain filling period followed by NPK or FYM alone which were similar. The control plots recorded fewer days to grain filling.

There was significant treatment interaction on effective grain filling period between variety and fertilizer in 2014/2015 and 2015/2016 at Kadawa (Table 46) and between sowing method and fertilizer at Kadawa in 2015/2016 (Table 47).

At Kadawa in 2014/2015, regardless of the variety used, fertilized plots took longer effective grain filling period except under LACRIWHIT-1 with combined NPK and

Table 45: Effective grain filling period of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	Effective grain filling period (days)					
	Samaru			**Kadawa**		
Treatment	2014/2015	2015/2016	combined	2014/2015	2015/2016	combined
Variety (V)						
LACRIWHIT-1	37.92b	38.50a	38.21a	30.25b	27.83c	29.04c
LACRIWHIT-4	32.42c	30.42b	31.92b	31.79b	29.96b	30.88b
LACRIWHIT-5	45.67a	36.17a	40.92a	38.54a	42.50a	40.52a
SE±	1.343	1.335	1.019	0.677	0.554	0.571
Sowing Method (S)						
Broadcast	38.89	35.50	37.19	33.42	33.58	33.50
Drill	39.11	34.56	36.83	33.64	33.28	33.46
SE±	1.096	1.090	0.832	0.553	0.452	0.466
Fertilizer (F)						
Control	40.94	40.94a	40.36a	34.33	31.44c	32.89
NPK (120: 60:60 kg ha^{-1})	37.50	32.11b	34.81b	33.17	33.50b	33.33
FYM (10 t ha^{-1})	39.67	34.17b	36.92b	34.56	33.28b	33.92
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	39.06	32.89b	35.97b	32.06	35.50a	33.78
SE±	1.550	1.512	1.177	0.781	0.639	0.659
Interaction						
Vx S	NS	NS	NS	NS	NS	NS
V x F	NS	NS	NS	**	*	NS
S x F	NS	NS	NS	NS	**	NS
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

Table 46: Interaction between variety and fertilizer on effective grain filling period at kadawa in 2014/2015 and 2015/2016 dry season

Treatment	Variety		
	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Fertilizer			
		2014/2015	
Control	31.17de	29.33ef	42.50a
NPK (120: 60:60 kg ha^{-1})	30.83de	32.00de	36.67bc
FYM (10 t ha^{-1})	32.17de	33.50cd	38.00b
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	26.83f	32.33de	37.00bc
SE± 1.353			
		2015/2016	
Control	24.33f	29.17de	40.83b
NPK (120: 60:60 kg ha^{-1})	27.83e	30.33cde	42.33ab
FYM (10 t ha^{-1})	27.67e	27.50e	44.67a
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	31.50cd	32.83c	42.17ab
SE± 2.748			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Table 47: Interaction between sowing method and fertilizer on effective grain filling period at Kadawa in 2015/2016 dry season

Treatment	Sowing Method	
	Broadcast	Drill
Fertilizer		
Control	33.22abc	29.67d
NPK (120: 60:60 kg ha^{-1})	31.78cd	35.22ab
FYM (10 t ha^{-1})	33.89abc	32.67bc
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	35.44a	35.56a
SE± 0.904		

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

FYM when it recorded the shortest grain filling period and the unfertilized which was at par with the remaining fertilized plots. Similar response between LACRIWHIT-1 and 4 was observed under the control, NPK alone as well as FYM alone. The highest variety x fertilizer was recorded in LACRIWHIT-5 under the control (Table 46). In 2015/2016 at Kadawa, LACRIWHIT-4 and 1 recorded similar grain filling period under NPK, FYM and their combination. When fertilizer was applied to LACRIWHIT-5 the fertilized plots recorded similar grain filling period. Under LACRIWHIT-4 all fertilizer treatments were at par except when combined NPK and FYM was applied (Table 46).

Table 47 presents interaction between sowing method and fertilizer at Kadawa in 2015/2016. When broadcast was adopted, statistically similar grain filling period was recorded under fertilizer treatment except when combined NPK and FYM was applied which excelled. There was no significant difference between sowing methods when FYM alone or combined with NPK was applied. The least grain filling period was observed in the unfertilized drilled wheat which statistically similar to broadcast fertilized with NPK alone.

4.2.15 Number of effective tiller m^{-2}

Table 48 shows the effect of sowing method and fertilizer on effective tillers of wheat varieties at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season and the combined mean. Varietal effect was significant only in the combined mean at Samaru and in 2014/2015 at Kadawa. At Samaru, LACRIWHIT-4 significantly produced more effective tillers than LACRIWHIT-1 but similar to LACRIWHIT-5. In 2014/2015 at Kadawa, LACRIWHIT-5 significantly had more effective tiller than LACRIWHIT-1 but statistically similar to LACRIWHIT-4. Sowing method had significant effect on effective tiller production in 2015/2016 at Samaru and 2014/2015 at Kadawa where drill sowing significantly produced more tillers than broadcast.

The fertilizer treatment had significant effect on number of effective tillers of wheat. Application of NPK alone and combined with FYM consistently produced high number of effective tillers except in 2015/2016 at both location when all the fertilized plots were at par. The control and FYM alone produced the least throughout the study except at Samaru in 2015/2016 season and the combined where it was at par with application of combined NPK and FYM. There was significant interaction between variety and sowing method in the combined mean at Kadawa (Table 49). There were no significant difference between broadcasting and drilling method when LACRIWHIT-1 or

Table 48: Number of effective tillers m^{-2} of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	Number of effective tillers m^{-2}					
	Samaru			**Kadawa**		
Treatment	2014/2015	2015/2016	combined	2014/2015	2015/2016	combined
Variety (V)						
LACRIWHIT-1	142.83	68.38	105.61b	103.17b	127.79	115.48
LACRIWHIT-4	199.67	115.25	157.46a	140.42ab	144.58	142.50
LACRIWHIT-5	179.00	90.17	134.58ab	175.42a	127.25	151.33
SE±	26.082	17.129	16.342	17.517	21.281	13.721
Sowing Method (S)						
Broadcast	169.67	67.03b	118.35	113.94b	149.33	131.64
Drill	178.00	115.50a	146.75	165.39a	117.08	141.24
SE±	21.300	13.986	13.343	14.302	17.376	19.404
Fertilizer (F)						
Control	83.33c	42.67b	63.00c	69.67b	78.89b	74.28b
NPK (120: 60:60 kg ha^{-1})	252.89a	131.11a	192.00a	191.67a	177.83a	184.75a
FYM (10 t ha^{-1})	150.00bc	100.06ab	125.03b	96.83b	107.11ab	101.97b
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	209.11ab	91.22ab	150.17ab	200.50a	169.00a	184.75a
SE±	30.188	19.779	18.870	20.227	24.573	15.843
Interaction						
Vx S	NS	NS	NS	NS	NS	*
V x F	NS	NS	NS	NS	NS	NS
S x F	NS	NS	NS	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

Table 49: Interaction between variety and sowing method on number of effective tiller m^{-2} at Kadawa in the combine mean of 2014/2015 and 2015/2016 dry season

Treatment		**Variety**	
Sowing Method	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Broadcast	170.83a	108.54b	115.54b
Drill	131.83ab	176.46a	115.42b
SE± 27.442			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

LACRIWHIT-5 were considered, while under LACRIWHIT-4 drilling appeared to statistically have higher number of effective tillers than broadcasting method. However, keeping sowing method constant and comparing the varieties, it was observed that LACRIWHIT-1 produced statistically more effective tillers than all varieties and under all sowing methods except under drilling when it was at par with LACRIWHIT-4 (Table 49).

4.2.16 Number of spike m^{-2}

Table 50 shows the number of spike of wheat varieties as affected by sowing method and fertilizer at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season and the combined mean. There was significant effect of variety on number of spike m^{-2} (Table 50). Variety LACRIWHIT-5 consistently produced the highest spikes m^{-2} than LACRIWHIT-1 throughout the study but at par with LACRIWHIT-4 except in 2015/2016 at Kadawa where LACRIWHIT-5 excelled LACRIWHIT-4. However, LACRIWHIT-1 had similar number of spikes m^{-2} to LACRIWHIT-4 throughout the study except in 2014/2015 at Kadawa where LACRIWHIT-4 was superior.

Sowing method was significant throughout except in 2014-2016 and combined mean at drill sowing recorded statistically highest number of spike throughout except in 2014/2015 and the combined at Samaru when it was not significant.

Application of NPK alone consistently produced more spike m^{-2} throughout but at par with FYM alone in 2014/2015 at Samaru and with combined NPK and FYM at Kadawa

Table 50: Number of Spike m^{-2} of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	Number of spike m^{-2}					
	Samaru			**Kadawa**		
Treatment	2014/2015	2015/2016	combined	2014/2015	2015/2016	combined
Variety (V)						
LACRIWHIT-1	355.67b	257.92b	306.79b	338.33b	372.79b	355.56b
LACRIWHIT-4	409.50ab	279.13ab	344.31ab	405.42a	367.63b	386.52ab
LACRIWHIT-5	450.00a	316.42a	383.21a	378.75ab	438.75a	408.75a
SE±	25.475	15.826	17.697	18.645	16.663	12.299
Sowing Method (S)						
Broadcast	401.22	253.36b	327.29	349.56b	367.89b	358.72b
Drill	408.89	315.61a	362.25	398.78a	418.22a	408.50a
SE±	20.800	12.922	14.450	15.224	13.606	10.042
Fertilizer (F)						
Control	289.56c	165.89c	227.72c	271.22b	284.00d	277.61c
NPK (120: 60:60 kg ha^{-1})	215.89a	365.78a	439.33a	458.22a	492.89a	475.56a
FYM (10 t ha^{-1})	434.89ab	317.17ab	350.03b	327.17b	361.89c	344.53b
NPK (60 :30 :30 kg ha$^{-1)}$+ FYM (5 t ha^{-1})	382.89b	289.11b	362.00b	440.06a	433.44b	436.75a
SE±	29.416	18.274	20.435	21.530	19.241	14.202
Interaction						
Vx S	NS	NS	NS	NS	NS	NS
V x F	NS	NS	NS	NS	NS	NS
S x F	NS	**	NS	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

Table 51: Interaction between sowing method and fertilizer on spike m^{-2} at Samaru in 2015/2016 dry season

Treatment	Sowing Method	
Fertilizer	Broadcast	Drill
Control	160.44c	171.33c
NPK (120: 60:60 kg ha^{-1})	328.44b	403.11a
FYM (10 t ha^{-1})	317.44b	316.89b
NPK (60 :30 :30 kg $ha^{-1)}$+ FYM (5 t ha^{-1})	207.11b	371.11ab
SE± 36.549		

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

in 2014/2015 and the combined. There was no significant difference between FYM alone and combined with NPK at Samaru while the unfertilized plots produced least number of spike m^{-2}. There was significant interaction between sowing method and fertilizer on spike m^{-2} at Samaru in 2015/2016 (Table 51). Drill sowing when supplied with NPK alone or in combination with FYM produced the highest spike m^{-2}. However, combined NPK and FYM was similar to FYM alone under drill and fertilized plots under broadcast. Regardless of sowing method, similar response was observed under the control, FYM alone and combined with NPK. The control produced the lowest number of spike m^{-2} in both sowing methods (Table 51).

4.2.17 Spike length (cm)

Table 52 shows effect of sowing method and fertilizer on spike length of wheat varieties in 2014/2015 and 2015/2016 dry seasons and the combined means at Samaru and Kadawa. There was significant difference among the varieties, LACRIWHIT-5 consistently had longer spike than LACRIWHIT-4 and 1 which were at par except in 2014/2015 and combined means at Samaru where it was similar to LACRIWHIT-1. Sowing method had no significant effect on spike length in both locations and the combined means. Fertilizer effect was significant on spike length except in 2014/2015 at Samaru and 2015/2016 at Kadawa.

Table 52: Spike length (cm) of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	Spike length (cm)					
	Samaru			**Kadawa**		
Treatment	2014/2015	2015/2016	combined	2014/2015	2015/2016	combined
Variety (V)						
LACRIWHIT-1	7.75ab	7.45b	7.60ab	8.63b	7.85b	8.24b
LACRIWHIT-4	6.78b	7.35b	7.06b	8.52b	7.42b	7.97b
LACRIWHIT-5	8.01a	8.11a	8.06a	9.45a	8.71a	9.08a
SE±	0.385	0.155	0.215	0.154	0.285	0.179
Sowing Method (S)						
Broadcast	7.73	7.61	7.67	8.71	8.16	8.44
Drill	7.29	7.67	7.48	9.02	7.83	8.43
SE±	0.315	0.127	0.176	0.125	0.233	0.146
Fertilizer (F)						
Control	6.72	6.55c	6.63c	7.53d	7.62	7.58c
NPK (120: 60:60 kg ha^{-1})	7.88	8.88a	8.38a	10.10a	8.56	9.33a
FYM (10 t ha^{-1})	7.92	6.88c	7.40b	8.31c	7.87	8.09c
NPK (60 :30 :30 kg $ha^{-1)}$+ FYM (5 t ha^{-1})	7.54	8.25b	7.89ab	9.52b	7.93	8.73b
SE±	0.445	0.180	0.249	0.177	0.330	0.206
Interaction						
Vx S	NS	NS	NS	NS	NS	NS
V x F	NS	NS	NS	NS	NS	NS
S x F	NS	NS	NS	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

Application of NPK alone consistently produced longest spikes except at the combined mean of Samaru where it was at par with combined application of NPK and FYM. The control statistically recorded the shortest spike throughout except in 2014/2015 at Samaru and the combined at Kadawa when it was to FYM alone. There was no significant interaction among the factors studied on spike length.

4.2.18 Number of spikelet spike^{-1}

Table 53 shows effect of treatment on number of spikelet spike^{-1} in 2014/2015 and 2015/2016 dry season and the combined means at Samaru and Kadawa. Varietal variation was significant only in 2015/2016 season at both locations (Table 53). LACRIWHIT-1 statistically produced more spikes than LACRIWHIT-4 but similar to LACRIWHIT-5 at Samaru while at Kadawa, LACRIWHIT-5 recorded higher spikelet spike^{-1} than LACRIWHIT-4 but at par with LACRIWHIT-1. The effect of sowing method was not significant on number spikelet spike^{-1} throughout the study.

Fertilizer had significant effect on number of spikelet spike^{-1} except in 2015/2016 at Kadawa. Application of NPK alone produced more spikelet spike^{-1} except in 2014/2015 combined analysis at both locations when all fertilized plots produced similar number of spikelet spike^{-1}. It was also at par with combined NPK and FYM in 2014-2016 at Kadawa. There was no significant interaction among the factors studied on number spikelet spike^{-1} (Table 53).

4.2.19 Number of sterile spikelet spike^{-1}

The influence of sowing method and fertilizer on sterile spikelet spike^{-1} of wheat varieties in 2014/2015 and 2015/2016 dry season and the combined means at Samaru and Kadawa is shown in Table 54. Number of sterile spikelet spike^{-1} was significantly affected by variety throughout the study except in 2015/2016 at Samaru (Table 54).

Table 53: Number of spikelets spike^{-1} of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	Number of spikelets spike^{-1}					
	Samaru			**Kadawa**		
Treatment	2014/2015	2015/2016	combined	2014/2015	2015/2016	combined
Variety (V)						
LACRIWHIT-1	12.55	13,28a	12.91	26.34	14.75ab	20.55
LACRIWHIT-4	12.60	11.98b	12.29	26.83	14.55b	20.19
LACRIWHIT-5	12.93	12.73ab	12.83	28.02	14.84a	21.43
SE±	0.328	0.298	0.226	1.076	0.429	1.188
Sowing Method (S)						
Broadcast	12.86	12.71	12.79	26.51	14.55	20.53
Drill	12.53	12.61	12.57	27.63	14.21	20.92
SE±	0.268	0.244	0.184	0.880	0.350	0.970
Fertilizer (F)						
Control	11.48b	11.24c	11.36b	21.51b	13.92	17.72b
NPK (120: 60:60 kg ha^{-1})	13.41a	14.63a	14.02a	31.89a	15.17	23.53a
FYM (10 t ha^{-1})	12.43ab	11.27c	11.85a	25.01b	14.21	19.61ab
NPK (60 :30 :30 kg ha$^{-1)}$+ FYM (5 t ha^{-1})	13.46a	13.50b	13.48a	29.85a	14.22	22.04a
SE±	0.379	0.344	0.261	1.244	0.495	1.372
Interaction						
Vx S	NS	NS	NS	NS	NS	NS
V x F	NS	NS	NS	NS	NS	NS
S x F	NS	NS	NS	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

Table 54: Number of sterile spikelets spike^{-1} of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	Number of sterile spikelets spike^{-1}					
	Samaru			**Kadawa**		
Treatment	2014/2015	2015/2016	combined	2014/2015	2015/2016	combined
Variety (V)						
LACRIWHIT-1	3.89b	3.78	3.34b	2.36b	2.73b	2.54b
LACRIWHIT-4	3.68b	2.93	3.31b	2.20b	2.52b	2.36b
LACRIWHIT-5	5.16a	3.36	4.26a	3.28a	3.67a	3.48a
SE±	0.293	0.312	0.230	0.213	0.222	0.150
Sowing Method (S)						
Broadcast	4.62a	3.38a	4.00a	2.89a	3.37b	3.13a
Drill	3.87b	2.67b	3.27b	2.34b	2.58a	2.46b
SE±	0.389	0.246	0.188	0.174	0.182	0.122
Fertilizer (F)						
Control	5.95a	4.07a	5.01a	3.86a	4.28a	4.07a
NPK (120: 60:60 kg ha^{-1})	2.86c	2.10c	2.48c	1.61c	1.75b	1.68d
FYM (10 t ha^{-1})	4.45b	3.24ab	3.89b	2.83b	3.13b	2.98b
NPK (60 :30 :30 kg ha$^{-1)}$+ FYM (5 t ha^{-1})	3.61bc	2.70bc	3.16bc	2.16bc	2.74b	2.45c
SE±	0.338	0.348	0.266	0.246	0.257	0.173
Interaction						
Vx S	NS	NS	NS	NS	NS	NS
V x F	NS	NS	NS	NS	NS	NS
S x F	NS	NS	NS	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

Variety LACRIWHIT-5 significantly had highest number of sterile spikelet spike^{-1} throughout the study than LACRIWHIT-4 and LACRIWHIT-1 which were at par. Sowing method had significant effect on number sterile spikelet spike^{-1}. Broadcast sowing significantly recorded highest number sterile spikelet throughout except in 2015/2016 at Kadawa where the drilled excelled. Fertilizer had significant effect on number of sterile spikelet spike^{-1}. Application of NPK alone and in combination with FYM had the lowest number of sterile spikelets except in combined mean at Kadawa where NPK alone excelled and 2015/2016 season at Kadawa where all fertilized plots were at par. The control plots had statistically the highest number of sterile spikelet spike^{-1} except in 2015/2016 at Samaru where it was similar to FYM. Interaction among factors was not significant on sterile spikelet spike^{-1} at both locations (Table 54).

4.2.20 Number of grain spike^{-1}

Table 55 presents effect of treatments on number of grain spike^{-1} of wheat. Variety LACRIWHIT-4 and LACRIWHIT-1 significantly recorded more number of grain spike^{-1} throughout the study than LACRIWHIT-5 except in 2015/2016 at Samaru where there was no significant difference among the varieties (Table 55). Sowing method had no significant effect on number of grain spike^{-1}. Application of NPK alone and in combination with FYM consistently and significantly produced the highest number of grain spike^{-1} except in 2014/2015 at Samaru where there was no significant difference among the fertilized plots and also at Kadawa in both years and combined where it was at par with combined NPK and FYM. At samaru in 2015/2016 and combined analysis where application of FYM alone and combined with NPK did record significant difference. The control produced the least number of grain spike^{-1} throughout the study. There was no significant interaction among the factors studied (Table 55).

Table 55: Number of grains spike^{-1} of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014-15 and 2015-16 dry season

	Number of grains spike^{-1}					
	Samaru			**Kadawa**		
Treatment	2014/2015	2015/2016	combined	2014/2015	2015/2016	combined
Variety (V)						
LACRIWHIT-1	30.55a	28.77	29.66a	32.17a	31.03a	31.60a
LACRIWHIT-4	28.00a	27.23	27.62a	30.23a	28.33a	29.28a
LACRIWHIT-5	22.01b	24.45	23.23b	23.89b	22.94b	23.42b
SE±	2.036	1.496	1.339	1.422	1.567	1.049
Sowing Method (S)						
Broadcast	28.63	27.36	27.99	27.81	27.85	27.83
Drill	25.08	26.28	25.68	29.72	27.01	28.37
SE±	1.662	1.221	1.093	1.164	1.280	0.857
Fertilizer (F)						
Control	19.78b	11.49c	15.68c	21.28b	20.73c	21.01c
NPK (120: 60:60 kg ha^{-1})	30.92a	39.00a	34.96a	35.77a	33.78a	34.57a
FYM (10 t ha^{-1})	27.48a	26.90b	27.19b	24.59b	25.97b	25.28b
NPK (60 :30 :30 kg ha$^{-1)}$+ FYM (5 t ha^{-1})	29.14a	29.88b	29.51b	33.42a	29.64ab	31.53a
SE±	2.351	1.727	1.546	1.642	1.810	1.212
Interaction						
Vx S	NS	NS	NS	NS	NS	NS
V x F	NS	NS	NS	NS	NS	NS
S x F	NS	NS	NS	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

4.2.21 Weight of grain spike^{-1} (g)

Table 56 shows effect of treatments on weight of grain spike^{-1} of wheat varieties in 2014/2015 and 2015/2016 dry season and the combined means at Samaru and Kadawa. Varietal effect was significant only in 2015/2016 at Samaru and Kadawa in the two years and combined (Table 56). Variety LACRIWHIT-5 produced statistically heavier grain spike^{-1} than LACRIWHIT-1 but at par with LACRIWHIT-4. However, LACRIWHIT-4 was similar to LACRIWHIT-1 at Kadawa in 2015/2016 and the combined.

There was no significant effect of sowing method on weight of grain spike^{-1} at both locations. Fertilizer had significant effect on weight of grain spike^{-1}. Application of NPK alone and in combination with FYM consistently produced heavier grain spike^{-1} except in 2015/2016 and combined means of Kadawa where, NPK alone excelled combined NPK and FYM and in 2014/2015 at Samaru where there was no significant difference among the fertilized plots. The control plots statistically recorded least weight of grain spike^{-1} except in 2014/2015 at Samaru where it was similar to FYM. There was no significant interaction among the factors studied (Table 56).

4.2.22 1000 grain weight (g)

Effects of sowing method and fertilizer on 1000 grain weight of wheat varieties in 2014/2015 and 2015/2016 dry seasons and the combined at Samaru and Kadawa is presented in Table 57. LACRIWHIT-5 significantly recorded the heaviest 1000 grain weight throughout the study than LACRIWHIT-4 and LACRIWHIT-1 which were at par (Table 57). Sowing method had no significant effect on 1000 grain weight. Application of fertilizer significantly affected 1000 grain weight of wheat throughout the study except in the combined at Samaru. The fertilized plots were similar and significantly produced heavier 1000 grain weight than the control except in 2014/2015

Table 56: Weight of grains spike^{-1} (g) of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	Weight of grains spike^{-1} (g)					
	Samaru			**Kadawa**		
Treatment	2014/2015	2015/2016	combined	2014/2015	2015/2016	combined
Variety (V)						
LACRIWHIT-1	1.08	0.62b	0.85	0.98b	0.99b	0.99b
LACRIWHIT-4	1.09	0.78a	0.94	1.19a	1.08ab	1.14ab
LACRIWHIT-5	1.01	0.81a	0.91	1.25a	1.20a	1.23a
SE±	0.081	0.048	0.053	0.059	0.055	0.042
Sowing Method (S)						
Broadcast	1.08	0.73	0.90	1.14	1.05	1.10
Drill	1.04	0.75	0.89	1.14	1.23	1.14
SE±	0.066	0.040	0.044	0.048	0.045	0.035
Fertilizer (F)						
Control	0.83b	0.30c	0.57c	0.82b	0.67c	0.74d
NPK (120: 60:60 kg ha^{-1})	1.16a	1.01a	1.09a	1.44a	1.48a	1.46a
FYM (10 t ha^{-1})	1.04ab	0.70b	0.87b	0.97b	1.05b	1.01c
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	1.21a	0.93a	1.07a	1.34a	1.27b	1.26b
SE±	0.093	0.060	0.062	0.068	0.063	0.049
Interaction						
Vx S	NS	NS	NS	NS	NS	NS
V x F	NS	NS	NS	NS	NS	NS
S x F	NS	NS	NS	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

Table 57: 1000 grain weight (g) of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	1000 grain weight (g)					
	Samaru			**Kadawa**		
Treatment	2014/2015	2015/2016	combined	2014/2015	2015/2016	combined
Variety (V)						
LACRIWHIT-1	36.67b	30.68b	33.68b	38.32b	33.68b	36.00b
LACRIWHIT-4	34.64b	29.32b	32.48b	36.91b	35.16b	36.04b
LACRIWHIT-5	42.07a	36.14a	39.11a	43.29a	37.83a	40.56a
SE±	1.027	0.952	0.844	1.630	0.646	0.898
Sowing Method (S)						
Broadcast	37.60	32.68	35.14	39.67	35.40	37.53
Drill	38.65	31.41	35.03	39.35	35.71	37.53
SE±	0.839	0.777	0.689	1.331	0.527	0.733
Fertilizer (F)						
Control	36.81b	29.86b	33.33	36.51b	30.57b	33.54b
NPK (120: 60:60 kg ha^{-1})	37.60ab	32.78ab	35.19	38.90ab	38.14a	38.52a
FYM (10 t ha^{-1})	37.62ab	33.53a	35.58	39.10ab	36.70a	37.90a
NPK (60 :30 :30 kg $ha^{-1)}$+ FYM (5 t ha^{-1})	40.49a	32.02ab	36.26	43.51a	36.81a	40.17a
SE±	1.186	1.099	0.974	3.541	0.746	1.037
Interaction						
Vx S	NS	NS	NS	NS	NS	NS
V x F	NS	NS	NS	NS	NS	NS
S x F	NS	NS	NS	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

at both locations where it was similar to application of NPK or FYM alone, and 2015/2016 at Samaru where it was at par with applied NPK alone or combined with FYM. There was no significant interaction among the factors studied on 1000 grain weight (Table 57).

4.2.23 Grain yield (kg ha^{-1})

Table 58 shows effects of sowing method and fertilizer on grain yield of three wheat varieties in 2014/2015 and 2015/2016 dry seasons and the combined at Samaru and Kadawa. The result revealed that there was significant variation in rain yield among the three wheat varieties tested. LACRIWHIT-5 consistently produced the highest grain yield except in 2014/2015 at both locations and the combine mean at Kadawa where it was observed to have statistically similar rain yield with LACRIWHIT-4. In 2015/2016 at both locations, LACRIWHIT-4 and LACRIWHIT-1 were at par while in the combined at Samaru LACRIWHIT-4 excelled LACRIWHIT-1 in grain yield. Sowing method significantly affected grain yield in both seasons and the combined where drill sown wheat consistently out yielded broadcast sown wheat except in 2014/2015 at Samaru where the sowing methods recorded similar grain yield.

Fertilizer application generally had significant effect on grain yield of wheat. Application of either NPK alone or combined with FYM produced the highest and statistically similar grain yield throughout the study except in 2014/2015 at Kadawa where NPK alone had the highest grain yield followed by combined NPK and FYM which was significantly higher than FYM alone. The control significantly produced least grain yield throughout the study.

There was significant interaction between variety and fertilizer in 2015/2016 at Samaru and in both years and the mean at Kadawa and between variety and sowing method in 2014/2015 at Kadawa (Table 59 and 60).

Table 58: Grain yield (kg ha^{-1}) of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	Grain yield (kg ha^{-1})					
	Samaru			Kadawa		
Treatment	2014/2015	2015/2016	combined	2014/2015	2015/2016	combined
Variety (V)						
LACRIWHIT-1	1465.0b	2003.95b	1734.46c	1990.9b	2815.3b	2403.1b
LACRIWHIT-4	1807.40a	2066.37b	1936.87b	2520.5a	2991.3b	2755.9a
LACRIWHIT-5	1826.4a	2526.54a	2176.45a	2506.8a	3436.5a	2971.6a
SE±	70.902	67.752	67.279	76.546	130.394	108.114
Sowing Method (S)						
Broadcast	1670.1	2072.00b	1871.03b	2160.03b	2902.5b	2531.3b
Drill	1729.1	2325.90a	2027.49a	2518.73a	3259.6a	2889.1a
SE±	57.891	55.319	54.933	62.499	106.466	88.275
Fertilizer (F)						
Control	976.0c	1094.40c	1035.20c	1162.3d	1263.7c	1213.0c
NPK (120: 60:60 kg ha^{-1})	2175.7a	2770.70a	2473.20a	3140.1a	4342.1a	3741.1a
FYM (10 t ha^{-1})	1701.3b	2185.20b	1943.30b	2324.5c	2625.4b	2475.0b
NPK (60 :30 :30 kg ha$^{-1)}$+ FYM (5 t ha^{-1})	1945.2a	2745.60a	2345.40a	2730.5b	4092.9a	3411.7a
SE±	81.870	78.234	77.687	588.388	150.566	124.839
Interaction						
Vx S	NS	NS	NS	*	NS	NS
V x F	NS	*	NS	*	*	*
S x F	NS	NS	NS	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

Table 59: Interaction between variety and fertilizer on yield (kg ha^{-1}) at Samaru in 2015/2016 and at Kadawa in 2014/2015, 2015/2016 dry season and combine mean

Treatment	Variety		
	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Fertilizer		**Samaru**	
		2015/2016	
Control	1120.0e	1172.4e	907.0e
NPK (120: 60:60 kg ha^{-1})	2388.9bc	2602.5b	3320.6a
FYM (10 t ha^{-1})	2033.4cd	1947.8d	2574.4b
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	2473.4b	2542.8b	3220.5a
SE± 191.63			
		Kadawa	
		2014/2015	
Control	1038.8d	1266.3d	1181.9d
NPK (120: 60:60 kg ha^{-1})	2409.7c	3533.5a	3477.9a
FYM (10 t ha^{-1})	2263.6c	2356.0c	2353.9c
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	2251.5c	2926.0b	3014.1b
SE± 216.50			
		2015/2016	
Control	1238.1gh	1707.5fg	845.6h
NPK (120: 60:60 kg ha^{-1})	3912.2c	4050.3bc	5063.8a
FYM (10 t ha^{-1})	2468.2e	2347.1ef	3061.0de
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	3642.9cd	3860.3c	4775.4ab
SE± 368.81			
		Combined	
Control	1138.4f	1486.9f	1013.8f
NPK (120: 60:60 kg ha^{-1})	3160.9cd	3791.9ab	4270.5a
FYM (10 t ha^{-1})	2365.9e	2351.6e	2707.4de
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	2947.2cde	3393.1bc	3894.7ab
SE± 305.79			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Table 60: Interaction between variety and sowing method on yield (kg ha^{-1}) at Kadawa in 2014/2015 dry season

Treatment	Variety		
	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Sowing Method			
Broadcast	1942.4c	2186.5bc	2351.1b
Drill	2039.4c	2854.4a	2662.4a
SE± 153.09			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

At Samaru in 2015/2016 irrespective of applied fertilizer, LACRIWHIT-1 and 4 recorded similar grain yield that was lower than that of LACRIWHIT-5. When fertilizer was fixed, LACRIWHIT-1 and 4 under NPK alone or combined with FYM produced similar grain yield that was lower than that of LACRIWHIT-5. Application of NPK alone or in combination with FYM to LACRIWHIT-5 recorded the highest grain yield while least yield was obtained from the control treatments irrespective of the varieties used (Table 59). In 2014/2015 at Kadawa, similar response in all the varieties was observed under no fertilizer FYM alone. LACRIWHIT-4 and 5 recorded similar grain yield under all fertilizer treatments. The grain yield in fertilized plots under LACRIWHIT-1 did not vary statistically. LACRIWHIT-4 and 5 receiving NPK alone out yielded any other variety x fertilizer combination while unfertilized treatment of all the three varieties recorded similar and least grain yield.

Irrespective of fertilizer applied, LACRIWHIT-1 and 4 resulted in similar grain yield at Kadawa in 2015/2016. All the varieties recorded statistically similar yield when FYM alone was applied. LACRIWHIT-5 receiving NPK alone or combined with FYM produced statistically highest grain yield while unfertilized LACRIWHIT-1 and 5 recorded the least.

In the combined mean at Kadawa, statistically similar response was observed in all the varieties under zero fertilizer and NPK alone. LACRIWHIT-4 and LACRIWHIT-5 recorded similar grain yield irrespective of fertilizer applied. LACRIWHIT-5 receiving NPK alone or combined with FYM and LACRIWHIT-4 under NPK alone produced highest and statistically similar grain yield while all the three varieties produced lowest yield when no fertilizer was applied (Table 59). Interaction between variety and sowing method at Kadawa in 2014/2015 shows that there was no statistical difference between broadcast and drill when LACRIWHIT-1 was considered. LACRIWHIT-4 and 5 statistically produced similar and highest grain under drill sowing. This was followed by LACRIWHIT-4 and LACRIWHIT-5 with similar yield when broadcast was done. However, broadcasted LACRIWHIT-4 was at par with the remaining interactions (Table 60).

4.2.24 Biomass yield (kg ha^{-1})

There was significant variation among the varieties for biomass throughout the study except in 2014/2015 and the combined mean at Kadawa (Table 61). Variety LACRIWHIT-5 significantly had the highest biomass throughout the study except in 2014/2015 at Samaru and in 2015/2016 at Kadawa, where variety LACRIWHIT-5 had statistically similar biomass with LACRIWHIT-4. Sowing method had no significant effect on biomass production but there was significant effect of fertilizer on biomass of wheat.

The application of NPK alone produced the highest biomass throughout the study except in 2014/2015 at both location and the combined mean at Kadawa where it was at par with NPK+FYM. Unfertilized plots recorded the least biomass yield except in 2015/2016 and combined at Samaru where there was no significant difference with remaining fertilizer treatments, while in 2014/2015 at Kadawa it was similar to FYM. There was significant interaction between variety and fertilizer in 2015/2016 at Kadawa (Table 62). At Kadawa in 2015/2016, all varieties recorded statistically similar biomass when no fertilizer was applied and when combined NPK and FYM was applied. Irrespective of fertilizer applied, LACRIWHIT-1 and 4 produced similar biomass yield. Highest biomass was observed when NPK alone or combined with FYM was applied to LACRIWHIT-5 this was at par with LACRIWHIT-4 supplied with NPK alone (Table 62).

Table 61: Biomass yield (kg ha^{-1}) of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

Treatment	Biomass yield (kg ha^{-1})					
	Samaru			Kadawa		
	2014/2015	2015/2016	combined	2014/2015	2015/2016	combined
Variety (V)						
LACRIWHIT-1	3892.3b	6837.5b	5364.9b	6756.7	7736.1b	7246.4
LACRIWHIT-4	5121.5a	5967.6b	5544.5b	7563.6	8048.6ab	7806.1
LACRIWHIT-5	4794.9a	9184.9a	6989.9a	6834.9	8663.2a	7749.1
SE±	190.403	533.475	380.936	347.720	298.441	272.990
Sowing Method (S)						
Broadcast	4590.9	7327.3	5959.1	6896.1	8064.8	7840.4
Drill	4614.9	7332.7	5973.8	7207.5	8233.8	7720.6
SE±	155.463	435.580	311.033	283.912	243.676	222.895
Fertilizer (F)						
Control	3044.8c	6901.2b	4973.0b	6128.1b	4689.8d	5409.0c
NPK (120: 60:60 kg ha^{-1})	5644.8a	9764.8a	7704.8a	8328.3a	11055.6a	9691.9a
FYM (10 t ha^{-1})	4503.6b	5630.8b	5067.2b	5959.6b	6865.8c	6412.7b
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	5218.3a	7023.2b	6120.8b	7791.1a	9986.1b	8888.6a
SE±	219.858	616.004	439.867	401.512	344.609	315.221
Interaction						
Vx S	NS	NS	NS	NS	NS	NS
V x F	NS	NS	NS	NS	*	NS
S x F	NS	NS	NS	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

Table 62: Interaction between variety and fertilizer on biomass (kg ha^{-1}) at kadawa in 2015/2016 dry season

	Variety		
Treatment	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Fertilizer			
Control	5181de	5264de	3625e
NPK (120: 60:60 kg ha^{-1})	10167b	10917ab	12083a
FYM (10 t ha^{-1})	5861d	6514d	8222c
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	9736bc	9500bc	10722ab
SE± 884.120			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

4.2.25 Harvest index (%)

Harvest index of wheat varieties as influenced by sowing method and fertilizer application during 2014/2015 and 2015/2016 dry season and the combine means at Samaru and Kadawa is shown in Table 63. Varieties significantly differed only in 2015/2016 at Samaru and 2014/2015 and the combine mean at Kadawa. LACRIWHIT-5 recorded highest harvest index except at Kadawa where it was similar to LACRIWHIT-4.

Sowing method effect was significant only at Kadawa in 2015/2016 when drilled wheat recorded higher harvest index than broadcast.

Fertilizer had significant effect on harvest index in the study. The fertilized plots were statistically similar but significantly higher than the control except in 2015/2016 at Samaru where FYM alone outperformed NPK alone and similar to combined NPK and FYM. Variety and fertilizer interaction on harvest index was significant only in 2014/2015 at Kadawa (Table 64). At Kadawa in 2014/2015, all varieties recorded similar harvest index under zero fertilizer and combined NPK and FYM. Highest harvest index was recorded by fertilized LACRIWHIT-5 but similar to LACRIWHIT-4 under NPK and FYM alone as well as LACRIWHIT-1 receiving FYM alone.

Table 63: Harvest index (%) of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014-15 and 2015-16 dry season

	Harvest index (%)					
	Samaru			Kadawa		
Treatment	2014/2015	2015/2016	combined	2014/2015	2015/2016	combined
Variety (V)						
LACRIWHIT-1	37.36	28.55b	32.95	30.46b	34.17	32.31b
LACRIWHIT-4	38.15	26.69b	32.42	33.43ab	34.46	33.95ab
LACRIWHIT-5	34.48	32.41a	33.44	36.29a	35.34	35.81a
SE±	1.229	1.839	1.305	1.404	1.017	0.811
Sowing Method (S)						
Broadcast	36.01	28.59	32.34	33.17	33.43b	33.30
Drill	37.24	29.84	33.54	33.62	35.89a	34.75
SE±	1.004	1.502	1.066	0.968	0.831	0.663
Fertilizer (F)						
Control	32.03b	21.35c	26.69b	20.18b	25.21b	22.70b
NPK (120: 60:60 kg ha^{-1})	38.89a	27.93b	33.41a	37.82a	39.27a	38.55a
FYM (10 t ha^{-1})	37.83a	36.32a	37.08a	39.63a	38.87a	38.25a
NPK (60 :30 :30 kg ha$^{-1)}$+ FYM (5 t ha^{-1})	37.90a	31.25ab	34.58a	35.93a	37.28a	36.61a
SE±	1.420	2.124	1.507	1.368	1.175	0.937
Interaction						
Vx S	NS	NS	NS	NS	NS	NS
V x F	NS	NS	NS	*	NS	NS
S x F	NS	NS	NS	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

Table 64: Interaction between variety and fertilizer on harvest index (%) at Kadawa in 2014/2015 dry season

	Variety		
Treatment	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Fertilizer			
Control	20.54e	18.70e	21.31e
NPK (120: 60:60 kg ha^{-1})	31.90cd	39.05ab	42.51a
FYM (10 t ha^{-1})	40.04ab	40.63ab	38.22abc
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	29.34d	35.35bcd	43.11a
SE± 3.352			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

4.3 Proximate and Gluten Content Analysis

4.3.1 Grain moisture content (%)

Table 65 shows the effect of sowing method and fertilizer on grain moisture content (%) of wheat varieties in 2014/2015 and 2015/2016 dry seasons and the combined at Samaru and Kadawa. The varieties varied significantly in 2014/2015 at Samaru and throughout at Kadawa. LACRIWHIT-1 recorded the least moisture content than LACRIWHIT-5 but at par with LACRIWHIT-4. Sowing method had no significant effect on grain moisture content in both locations.

The effect of fertilizer on grain moisture content was significant at both locations with the control plots and FYM alone having the least moisture content throughout the study except in 2015/2016 at Samaru when they were at par with NPK alone. Highest moisture content was observed when NPK alone or combined with FYM was applied throughout the study except at Kadawa in the combined mean when combine NPK and FYM excelled. Significant interaction between sowing method and fertilizer on wheat moisture content was recorded at Kadawa in the combined mean (Table 66).

When fertilizer was applied, similar moisture content was observed under NPK and FYM alone under both sowing method. When fertilizer was fixed, zero fertilizer and NPK alone recorded similar moisture content under broadcast while in drill sowing, NPK alone and combined with FYM also recorded similar moisture content (Table 66).

Table 65: Grain moisture content (%) of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	Grain moisture content (%)					
	Samaru			**Kadawa**		
Treatment	2014/2015	2015/2016	combined	2014/2015	2015/2016	combined
Variety (V)						
LACRIWHIT-1	8.57b	9.46	9.02	8.89b	9.31b	9.10b
LACRIWHIT-4	9.04ab	9.13	9.08	9.15ab	9.60ab	9.38ab
LACRIWHIT-5	9.13a	9.57	9.35	9.50a	9.79a	9.65a
SE±	0.174	0.201	0.181	0.161	0.142	0.110
Sowing Method (S)						
Broadcast	8.69b	9.39	9.04	9.22	9.48	9.35
Drill	9.14a	9.39	9.26	9.14	9.66	9.40
SE±	0.142	0.164	0.148	0.131	0.116	0.090
Fertilizer (F)						
Control	8.00b	8.84c	8.42b	8.74b	9.01b	8.87c
NPK (120: 60:60 kg ha^{-1})	9.40a	9.59ab	9.50a	9.37a	9.78a	9.67b
FYM (10 t ha^{-1})	8.56b	8.99bc	8.78b	8.75b	9.08b	8.92c
NPK (60 :30 :30 kg ha$^{-1)}$+ FYM (5 t ha^{-1})	9.69a	10.12a	9.91a	9.86a	10.20a	10.03a
SE±	0.201	0.232	0.209	0.186	0.164	0.128
Interaction						
Vx S	NS	NS	NS	NS	NS	NS
V x F	NS	NS	NS	NS	NS	NS
S x F	NS	NS	NS	NS	NS	**
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

Table 66: Interaction between sowing method and fertilizer on grain moisture content (%) of wheat at Samaru 2015/2016 dry season

	Sowing method	
Treatment	Broadcast	Drill
Fertilizer		
Control	9.16cd	8.59e
NPK (120: 60:60 kg ha^{-1})	9.50bc	9.85ab
FYM (10 t ha^{-1})	8.98de	8.85de
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	9.75b	10.31a
SE± 0.180		

4.3.2 Ash content (%)

Effect of sowing method and fertilizer on grain ash content of wheat varieties in 2014/2015 and 2015/2016 dry season and the combined at Samaru and Kadawa is presented in Table 67. Varietal effect was significant only at Samaru when varieties LACRIWHIT-1 and 4 were at par and recorded more ash content than LACRIWHIT-5. Sowing method did not affect ash content throughout the study.

Fertilizer application had significant effect on ash content at both locations. The unfertilized plots consistently recorded the highest ash content throughout the study but at par with application of FYM alone at Samaru throughout and also similar to combined NPK and FYM at Samaru in 2015/2016 season. The least ash content was recorded when NPK alone or combined with FYM. There was significant interaction between variety and sowing method at Kadawa in the combined mean and between variety and fertilizer in 2014/2015 and the combined mean at Kadawa.

In the combined mean at Kadawa, when broadcast was adopted, similar ash content recorded in all the varieties. LACRIWHIT-4 and 5 were at par in ash content under both sowing methods (Table 68). Table 69 shows the interaction between variety and fertilizer on ash content in 2014/2015 and combined mean at Kadawa. In 2014/2015, when fertilizer was applied, similar ash content was recorded under all varieties except

Table 67: Ash content (%) of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	Ash content (%)					
	Samaru			Kadawa		
Treatment	2014/2015	2015/2016	combined	2014/2015	2015/2016	combined
Variety (V)						
LACRIWHIT-1	8.68a	9.31a	9.00a	8.11	8.61	8.36
LACRIWHIT-4	9.33a	9.35a	9.34a	7.92	8.30	8.11
LACRIWHIT-5	7.12b	7.91b	7.52b	7.45	8.03	7.74
SE±	0.440	0.472	0.314	0.298	0.400	0.235
Sowing Method (S)						
Broadcast	8.77	8.74	8.76	7.82	8.17	8.00
Drill	7.97	8.98	8.48	7.83	8.45	8.14
SE±	0.340	0.385	0.256	0.244	0.325	0.192
Fertilizer (F)						
Control	9.40a	9.73a	9.56a	9.67a	10.05a	9.86a
NPK (120: 60:60 kg ha^{-1})	7.34c	7.95b	7.65c	7.27bc	7.52b	7.39bc
FYM (10 t ha^{-1})	8.98ab	9.01ab	9.00ab	7.74b	8.29b	8.01b
NPK (60 :30 :30 kg $ha^{-1)}$+ FYM (5 t ha^{-1})	7.78bc	8.75ab	8.27bc	6.61c	7.39b	7.00c
SE±	0.508	0.545	0.362	0.344	0.459	0.271
Interaction						
Vx S	NS	NS	NS	NS	NS	*
V x F	NS	NS	NS	*	NS	*
S x F	NS	NS	NS	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

Table 68: Interaction between variety and sowing method on Ash content (%) at Kadawa in the combine mean

Treatment	**Variety**		
Sowing Method	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Broadcast	7.79b	8.19ab	8.01ab
Drill	8.93a	8.03ab	7.46b
SE± 0.332			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Table 69: Interaction between variety and fertilizer on Ash content (%) at Kadawa in 2014/2015 and combine mean

	Variety		
Treatment	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Fertilizer		**Kadawa 2014/2015**	
Control	8.83ab	9.94a	10.23a
NPK (120: 60:60 kg ha^{-1})	8.98ab	6.94cde	5.90e
FYM (10 t ha^{-1})	8.19bc	8.02bcd	7.01cde
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	6.45de	6.76cde	6.64cde
SE± 0.596			
		Combined	
Control	9.13ab	10.03a	10.41a
NPK (120: 60:60 kg ha^{-1})	8.69b	7.17de	6.32e
FYM (10 t ha^{-1})	8.56bc	8.19bcd	7.28cde
NPK (60 :30 :30 kg ha^{-1})+ FYM (5 t ha^{-1})	7.04de	7.03de	6.93de
SE± 0.469			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

NPK alone. Regardless of the fertilizer applied, similar ash content was observed in LACRIWHIT-1 under control, NPK and FYM alone also in LACRIWHIT-4 and 5 under all fertilized plots. Similar trend was observed in the combined mean at Kadawa.

4.3.3 Fibre content (%)

The effect of sowing method and fertilizer on fibre content of wheat varieties in 2014/2015 and 2015/2016 dry season and the combined at Samaru and Kadawa is presented in Table 70. Varietal effect on fibre content was significant only in 2014/2015 and combined mean at Samaru. LACRIWHIT-4 recorded the highest fibre content than LACRIWHIT-5 but at par with LACRIWHIT-1. Sowing method had no significant

Table 70: Fibre content (%) of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	Fibre content (%)					
	Samaru			**Kadawa**		
Treatment	2014/2015	2015/2016	combined	2014/2015	2015/2016	combined
Variety (V)						
LACRIWHIT-1	5.34ab	4.56	4.95ab	4.39	4.67	4.53
LACRIWHIT-4	5.56a	4.99	5.27a	4.79	4.83	4.81
LACRIWHIT-5	4.75b	4.85	4.80b	4.42	4.78	4.60
SE±	0.247	0.193	0.160	0.161	0.171	0.117
Sowing Method (S)						
Broadcast	4.99	4.88	4.94	4.59	4.72	4.65
Drill	5.45	4.71	5.08	4.48	4.80	4.64
SE±	0.202	1.158	0.131	0.131	0.140	0.096
Fertilizer (F)						
Control	5.54	5.07	5.31a	4.44	4.64	4.54
NPK (120: 60:60 kg ha^{-1})	4.93	4.56	4.74b	4.40	4.83	4.62
FYM (10 t ha^{-1})	5.07	4.99	5.03ab	4.70	4.86	4.78
NPK (60 :30 :30 kg ha$^{-1)}$+ FYM (5 t ha^{-1})	5.33	4.56	4.95ab	4.59	4.71	4.65
SE±	0.286	0.223	0.185	0.185	0.197	0.135
Interaction						
Vx S	NS	NS	NS	**	NS	*
V x F	NS	NS	NS	NS	NS	NS
S x F	NS	NS	NS	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

effect on fibre content. Fertilizer application had significant effect on fibre content only in the combined mean at Samaru. The fertilized plots were at and recorded similar fibre content, however, the control did not differ with FYM alone and combined with NPK. Significant interaction between variety and sowing method was observed in 2014/2015 and the combined mean at Kadawa (Table 71). At Kadawa in 2014/2015, when drill was employed, similar fibre content was recorded in all the varieties. LACRIWHIT-1 and 5 did not differ in their fibre content under both sowing methods. Similar response was observed in the combined analysis (Table 71).

Table 71: Interaction between variety and sowing method on fibre content (%) at Kadawa in 2014/2015 and the combine mean

Treatment		**Variety**		
Sowing Method		LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
			2014/2015	
Broadcast		4.16b	5.27a	4.33b
Drill		4.63ab	4.31b	5.51b
SE±	0.227			
			Combined	
Broadcast		4.40b	5.08a	4.47b
Drill		4.67ab	4.55b	4.72ab
SE±	0.166			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

4.3.4 Lipid content (%)

Table 72 shows the effect of sowing method and fertilizer on lipid content of wheat varieties in 2014/2015 and 2015/2016 dry season and the combined at Samaru and Kadawa. Significant effect of variety on lipid content was observed only in the combined mean at Kadawa when LACRIWHIT-5 recorded higher lipid content than LACRIWHIT-1 but at par with LACRIWHIT-4. Sowing method did not affect lipid content in both locations.

Fertilizer application had significant effect on lipid content. Application of NPK alone or combined with FYM consistently produced highest lipid content except in 2014/2015

Table 72: Lipid content (%) of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	Lipid content (%)					
	Samaru			Kadawa		
Treatment	2014/2015	2015/2016	combined	2014/2015	2015/2016	combined
Variety (V)						
LACRIWHIT-1	1.80	1.57	1.68	1.60	1.61	1.61b
LACRIWHIT-4	1.85	1.60	1.73	1.70	1.81	1.76ab
LACRIWHIT-5	1.83	1.46	1.65	1.80	1.85	1.82a
SE±	0.052	0.069	0.053	0.088	0.083	0.059
Sowing Method (S)						
Broadcast	1.86	1.58	1.72	1.65	1.79	1.72
Drill	1.79	1.51	1.65	1.75	1.73	1.74
SE±	0.043	0.057	0.043	0.072	0.068	0.048
Fertilizer (F)						
Control	1.48c	1.31b	1.39c	1.41b	1.49b	1.45b
NPK (120: 60:60 kg ha^{-1})	1.90b	1.77a	1.83a	1.84a	1.91a	1.87a
FYM (10 t ha^{-1})	1.85b	1.42b	1.62b	1.73a	1.76ab	1.75a
NPK (60 :30 :30 kg ha$^{-1)}$+ FYM (5 t ha^{-1})	2.09a	1.68a	1.88a	1.83a	1.87a	1.85a
SE±	0.060	0.080	0.061	0.102	0.096	0.068
Interaction						
Vx S	**	NS	NS	NS	NS	NS
V x F	NS	*	NS	NS	NS	NS
S x F	NS	NS	NS	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

at Samaru when NPK+FYM excelled and throughout at Kadawa where all the fertilized plots were at par. The unfertilized plots recorded the least lipid content except in 2015/2016 at both locations when it was at par with the application of FYM alone. There was significant interaction between variety and sowing method (Table 73) and between variety and fertilizer (Table 74) on lipid content of wheat at Samaru in 2014/2015 and 2015/2016 respectively.

Table 73 shows the interaction between variety and sowing method at Samaru in 2014/2015 season. LACRIWHIT-1 and 4 recorded similar lipid content under broadcast sowing while LACRIWHIT-4 and 5 were at par when drill was employed. LACRIWHIT-4 produced similar lipid at both sowing methods.

Interaction between variety and fertilizer on lipid content of wheat at Samaru in 2015/2016 season is presented in Table 74. Regardless of variety used, application of FYM alone or in combination with NPK resulted in similar lipid content in all the varieties. LACRIWHIT-1 and 5 produced similar lipid content when fertilizer was applied. Highest lipid was recorded by LACRIWHIT-4 under NPK alone which was at par with LACRIWHIT-5 fertilized with combined NPK and FYM.

Table 73: Interaction between variety and sowing method on Lipid content (%) at Samaru in 2014/2015 dry season

		Variety	
Treatment	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Sowing Method			
Broadcast	1.99a	1.89ab	1.71bc
Drill	1.60c	1.82ab	1.95a
SE± 0.074			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Table 74: Interaction between variety and fertilizer on Lipid content (%) at Samaru 2015/2016 dry Season

	Variety		
Treatment	LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
Fertilizer			
Control	1.36cde	1.52bcd	1.07e
NPK (120: 60:60 kg ha^{-1})	1.66bc	2.12a	1.53bcd
FYM (10 t ha^{-1})	1.54bcd	1.22de	1.50bcd
NPK (60 :30 :30 kg $ha^{-1)}$+ FYM (5 t ha^{-1})	1.71bc	1.57bcd	1.77ab
SE± 0.139			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

4.3.5 Protein content (%)

The effect of sowing method and fertilizer on protein content of wheat varieties in 2014/2015 and 2015/2016 dry season and the combined at Samaru and Kadawa is shown in Table 75. The varieties significantly varied in their protein content throughout the study. LACRIWHIT-1 recorded the highest protein content at both locations than LACRIWHIT-4 and 5 except in 2015/2016 at Kadawa when it was similar to LACRIWHIT-5. LACRIWHIT-1 and 4 were at par except in 2014/2015 and combined mean at Samaru when LACRIWHIT-5 excelled. Sowing method had no significant effect on protein content of wheat but was significantly affected by fertilizer application.

Application of NPK alone and combined with FYM statistically recorded highest protein content throughout the study except in 2014/2015 at Samaru when NPK alone excelled and in 2015/2016 when NPK was similar to FYM. Also at Kadawa in 2015/2016 there was no significant difference among all fertilized plots. The control plots recorded the least protein content except in 2014/2015 at Samaru when combined NPK and FYM produced the least and in 2015/2016 at Kadawa when it was at par with application of FYM alone. There was no significant interaction among the factors studied.

Table 75: Protein content (%) of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	Protein content (%)					
	Samaru			**Kadawa**		
Treatment	2014/2015	2015/2016	combined	2014/2015	2015/2016	combined
Variety (V)						
LACRIWHIT-1	12.27a	12.29a	12.28a	13.09a	12.10a	12.59a
LACRIWHIT-4	10.08c	10.56b	10.32c	10.98b	10.50b	10.74b
LACRIWHIT-5	11.12b	10.92b	11.02b	11.55b	11.19ab	11.37b
SE±	0.284	0.292	0.192	0.263	0.365	0.229
Sowing Method (S)						
Broadcast	10.85	11.13	10.99	11.70	11.15	11.43
Drill	11.45	11.39	11.42	12.04	11.37	11.70
SE±	0.232	0.238	0.157	0.489	0.298	0.187
Fertilizer (F)						
Control	9.89b	9.99c	9.94c	10.46b	9.99b	10.22c
NPK (120: 60:60 kg ha^{-1})	11.88a	11.80ab	11.84a	12.46a	11.95a	12.21a
FYM (10 t ha^{-1})	10.74b	11.10b	10.92b	11.91a	11.02ab	11.47b
NPK (60 :30 :30 kg $ha^{-1)}$+ FYM (5 t ha^{-1})	12.11c	12.14a	12.12a	12.66a	12.07a	12.37a
SE±	0.328	0.337	0.222	0.352	0.422	0.265
Interaction						
Vx S	NS	NS	NS	NS	NS	NS
V x F	NS	NS	NS	NS	NS	NS
S x F	NS	NS	NS	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

4.3.6 Carbohydrate content (%)

Table 76 shows the effect of sowing method and fertilizer on carbohydrate content of wheat varieties in 2014/2015 and 2015/2016 dry season and the combined at Samaru and Kadawa. Varietal variation was significant on carbohydrate content with LACRIWHIT-5 consistently recording the highest carbohydrate content but at par with LACRIWHIT-4 except in 2014/2015 and the combine mean at Samaru where LACRIWHIT-5 excelled. LACRIWHIT-1 was similar to LACRIWHIT-4 in 2014/2015 at Samaru and similar to LACRIWHIT-5 at Kadawa in 2014/2015 and 2015/2016 dry season.

Sowing method did not affect the carbohydrate content throughout the study but was significantly affected by fertilizer at Samaru. The fertilized plots were at par and significantly produced higher carbohydrate than the control except in 2014/2015 and 2015/2016 when it was similar to application of NPK alone in both years and when combined with FYM in 2015/2016. There was significant interaction between variety and sowing method on carbohydrate content of wheat in 2014/2015 at both locations (Table 77).

At Samaru, there was no significant difference between broadcasting and drilling wheat when LACRIWHIT-1 and 4 were considered, while under broadcasting LACRIWHIT-5 statistically recorded the highest carbohydrate content than the drilled. Keeping sowing methods constant and viewing varieties, LACRIWHIT-1 and 4 recorded similar carbohydrate content. At Kadawa in 2014/2015, all varieties recorded similar carbohydrate content under broadcasting which were at par with drilled LACRIWHIT-1 and 4. Regardless of sowing methods, LACRIWHIT-1 and 4 recorded similar carbohydrate content which were at par with LACRIWHIT-5 under broadcast (Table 77).

Table 76: Carbohydrate content (%) of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

	Carbohydrate content (%)					
	Samaru			**Kadawa**		
Treatment	2014/2015	2015/2016	combined	2014/2015	2015/2016	combined
Variety (V)						
LACRIWHIT-1	63.34b	62.81b	63.07c	63.92b	63.70b	63.81b
LACRIWHIT-4	66.15b	64.38a	64.26b	65.46a	64.96a	65.21a
LACRIWHIT-5	66.04a	65.28a	65.66a	65.28ab	64.37ab	64.83a
SE±	0.486	0.543	0.353	0.501	0.389	0.338
Sowing Method (S)						
Broadcast	64.82	64.29	64.55	65.02	64.69	64.85
Drill	64.21	64.02	64.11	64.75	64.00	64.38
SE±	0.397	0.443	0.288	0.409	0.317	0.276
Fertilizer (F)						
Control	62.99b	62.75b	62.87b	64.44	63.75	64.10
NPK (120: 60:60 kg ha^{-1})	64.55ab	65.33ab	64.44a	64.66	63.81	64.24
FYM (10 t ha^{-1})	64.80a	64.49ab	64.65a	65.16	64.98	65.07
NPK (60 :30 :30 kg $ha^{-1)}$+ FYM (5 t ha^{-1})	65.70a	65.05a	65.37a	65.28	64.83	65.05
SE±	0.562	0.627	0.408	0.579	0.450	0.391
Interaction						
Vx S	*	NS	NS	*	NS	NS
V x F	NS	NS	NS	NS	NS	NS
S x F	NS	NS	NS	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

Table 77: Interaction between variety and sowing method on Carbohydrate content (%) at Samaru and Kadawa in 2014/2015 dry season

Treatment		**Variety**		
Sowing Method		LACRIWHIT-1	LACRIWHIT-4	LACRIWHIT-5
			Samaru	
Broadcast		63.79bc	63.46bc	67.20a
Drill		62.89c	64.84bc	64.89b
SE±	0.688			
			Kadawa	
Broadcast		64.67ab	65.24a	65.17a
Drill		66.25a	65.32a	62.67b
SE±	0.709			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

4.3.7 Gluten Content

Effect of sowing method and fertilizer on gluten content of wheat varieties in 2014/2015 and 2015/2016 dry season and the combined at Samaru and Kadawa is presented in Table 78. There was significant difference among the varieties on gluten content. LACRIWHIT-1 consistently recorded the highest gluten content but at par with LACRIWHIT-5 at Kadawa in 2015/2016. LACRIWHIT-4 had the least gluten content but similar to LACRIWHIT-5 in 2015/2016 at Samaru and in 2014/2015 and 2015/2016 at Kadawa. Sowing method significantly affected gluten content in 2014/2015 and the combined mean at Samaru with the drilled having higher gluten content.

Fertilizer application significantly affected gluten content of wheat at both locations. Application of NPK alone and combined with FYM recorded significantly the highest gluten content except in 2014/2015 and combined mean at both locations where NPK alone was similar to FYM alone. Similarly, in 2015/2016 at Samaru as well as 2014/2015 and 2015/2016 at Kadawa, there was no significant difference among all fertilized plots. The control plots produced statistically least gluten content throughout the study except in 2015/2016 at Kadawa when it was similar to FYM alone. There was no significant interaction among the factors studied

Table 78: Dry gluten content of wheat varieties as influenced by sowing method and fertilizer application at Samaru and Kadawa in 2014/2015 and 2015/2016 dry season

Treatment	Gluten content (%)					
	Samaru			Kadawa		
	2014/2015	2015/2016	combined	2014/2015	2015/2016	combined
Variety (V)						
LACRIWHIT-1	9.72a	9.74a	9.73a	10.33a	9.59a	9.96a
LACRIWHIT-4	7.45c	8.05b	7.90c	8.22b	7.99b	8.11c
LACRIWHIT-5	8.56b	8.37b	8.46b	8.79b	8.68ab	8.73b
SE±	0.281	0.278	0.188	0.299	0.359	0.221
Sowing Method (S)						
Broadcast	8.28b	8.57	8.43b	8.94	8.64	8.79
Drill	8.95a	8.87	8.91a	9.21	8.86	9.09
SE±	0.229	0.227	0.153	0.244	0.293	0.181
Fertilizer (F)						
Control	7.33c	7.50b	7.41c	7.68b	7.46b	7.57c
NPK (120: 60:60 kg ha^{-1})	9.13ab	9.02a	9.08ab	9.59a	9.35a	9.47ab
FYM (10 t ha^{-1})	8.40b	8.77a	8.59b	9.27a	8.61ab	8.94b
NPK (60 :30 :30 kg ha$^{-1)}$+ FYM (5 t ha^{-1})	9.60a	9.59a	9.59a	9.92a	9.58a	9.75a
SE±	0.324	0.321	0.217	0.345	0.415	0.256
Interaction	NS	NS	NS	NS	NS	NS
Vx S	NS	NS	NS	NS	NS	NS
V x F	NS	NS	NS	NS	NS	NS
S x F	NS	NS	NS	NS	NS	NS
V x S x F	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

4.4 Correlation Analysis

4.4.1. Correlation analysis at Samaru

The result of correlation analysis between grain yield, growth and yield components of three wheat varieties in 2014/2015, 2015/2016 and the combined data in Samaru are shown in Tables 79–81. In 2014/2015, grain yield was found to be significantly and positively correlated with stand count m^{-2} (0.237*), plant height at harvest (0.359**), number of tillers m^{-2} (0.385**), leaf Area Index (0.351**), crop dry matter (0.551**), crop growth rate (0.265*), spike m^{-2} (0.395**), spikelets $spike^{-1}$ (0.304**), weight of grains $spike^{-1}$ (0.238*), total biomass (0.915**) and harvest index (0.510**). Yield also significantly but negatively correlated with net assimilation rate (-0.241*), days to 50% heading (-0.259*), days to 50% flowering (-0.280*), days to maturity (-0.285*) and sterile spikelets $spike^{-1}$ (-0.339**). Whereas the spike length (0.127), number of grains $spike^{-1}$ (0.221), 1000 grain weight (0.118) and relative growth rate (-0.001) did not significantly correlate with the grain yield. Number of tillers m^{-2} significantly and positively correlated with leaf Area Index (0.352**), crop dry matter (0.401**), total biomass (0.296*) and harvest index (0.261*). But not significant weight of grains $spike^{-1}$ (0.081). Leaf Area Index significantly correlated with crop dry matter (0.598**), total biomass (0.429**) and harvest index (0.370**) but no significant correlation with weight of grains $spike^{-1}$ (0.207**). Weight of grains $spike^{-1}$ recorded not significant relation with all parameters. Similarly total biomass and harvest index recoded non significant (0.140) correlation. (Table 79).

In 2015/2016, grain yield was found to be significantly and positively correlated with stand count m^{-2} (0.414**), plant height at harvest (0.551**), number of tillers m^{-2} (0.597**), leaf Area Index (0.448**), crop dry matter (0.645**), crop growth rate (0.569**), spike m^{-2} (0.453**), spike length (0.646**), spikelets $spike^{-1}$ (0.460**), number of grains spike^{-1} (0.612**), weight of grains spike^{-1} (0.582**), 1000 grain weight (0.331**) and total biomass (0.325**). Grain yield significantly but negatively correlated with days to 50% heading (-0.486**), days to 50% flowering (-0.489**), days to maturity (-0.269*) and sterile spikelets spike^{-1} (-0.380**) while the grain yield did not significantly correlate with harvest index (0.224), relative growth rate (0.207) and net assimilation rate (0.074). Number of tillers m^{-2} significantly and positively correlated with crop dry matter, weight of grains spike^{-1}, total biomass and harvest index. Leaf Area Index significantly correlated with crop dry matter and weight of grains spike^{-1} but not significant with total biomass and harvest index. Weight of grains spike^{-1} recorded significantly with harvest index however not significant with total biomass. The relationship between total biomass and harvest index positive and significant.(Table 80).

In the combined mean at Samaru, grain yield was found to be significantly and positively correlated with stand count m^{-2} (0.246*), number of tillers m^{-2} (0.574**), leaf Area Index (0.309**), crop dry matter (0.546**), crop growth rate (0.330**), spike m^{-2} (0.212*), spike length (0.339**), spikelets spike^{-1} (0.369**), number of grains spike^{-1} (0.434**), weight of grains spike^{-1} (0.238**) and total biomass (0.535**). Days to 50% flowering (-0.222**), days to maturity (0.331**) and sterile spikelets spike^{-1} (0.411**) were significantly but negatively correlated with yield. There was no significant correlation between grain yield and days to 50% heading (-0.136), 1000 grain weight (0.033), harvest index (0.132), plant height at harvest (-0.022), relative growth rate (0.012) and net assimilation rate (-0.014). Number of tillers m^{-2} significantly and positively correlated with leaf Area Index and crop dry matter, total biomass while negatively correlated with harvest index. But not significant with weight

Table 79: Matrix of correlation coefficient between grain yield, growth and yield components of three wheat varieties at Samaru during 2014/2015 dry season

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.000															
2	0.359**	1.000														
3	0.353**	0.315**	1.000													
4	0.531**	0.502**	0.352**	1.000												
5	0.551**	0.669**	0.401**	0.598**	1.000											
6	0.265*	0.499**	0.303**	0.424**	0.810**	1.000										
7	-0.280*	-0.630**	-0.206	-0.459**	-0.633**	-0.505**	1.000									
8	-0.285*	-0.519**	-0.135	-0.125	-0.457**	-0.195	0.359**	1.000								
9	0.395**	0.479**	0.318**	0.509**	0.404**	0.201	-0.278*	-0.322**	1.000							
10	0.127	0.113	0.146	0.179	0.206	0.309**	-0.139	0.192	0.026	1.000						
11	0.304**	0.279*	0.310**	0.432**	0.446**	0.329**	-0.187	-0.079	0.170	0.560**	1.000					
12	0.221	-0.542**	0.069	0.238*	0.447**	0.311**	-0.414**	-0.290*	0.234*	0.193	0.482**	1.000				
13	0.238*	0.363**	0.081	0.207	0.381**	0.291*	-0.290*	-0.209	0.160	0.086	0.430**	0.835**	1.000			
14	0.118	-0.180	0.055	0.135	0.060	0.213	0.095	0.222	-0.135	0.059	0.066	-0.180	0.268	1.000		
15	0.915**	0.275*	0.296*	0.429**	0.471**	0.174	0.234	-0.301*	0.373**	0.147	0.276*	0.207	0.240	0.109	1.000	
16	0.510**	0.300*	0.261*	0.370**	0.345**	0.269*	0.181	-0.047	0.180	0.008	0.143	0.150	0.119	0.055	0.140	1.00

Df=n-2= (70); r at 5% = 0.0.232; at 1 % = 0.308; **=Significant 1% level of probability; *=Significant 5% level of probability

1. Yield kg ha^{-1}
2. Plant height at harvest
3. Number of tillers m^{-2}
4. Leaf Area Index
5. Crop dry matter
6. Crop growth rate
7. Days to 50% flowering
8. Days to maturity
9. Spike m^{-2}
10. Spike length
11. Spikelets $spike^{-1}$
12. Number of grains $spike^{-1}$
13. Weight of grains $spike^{-1}$
14. 1000 grain weight
15. Total biomass
16. Harvest index

Table 80: Matrix of correlation coefficient between grain yield, growth and yield components of three wheat varieties at Samaru during 2015/2016 dry season

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.000															
2	0.551**	1.000														
3	0.597**	0.467**	1.000													
4	0.448**	0.467**	0.394**	1.000												
5	0.645**	0.660**	0.618**	0.541**	1.000											
6	0.569**	0.540**	0.400**	0.319**	0.819**	1.000										
7	-0.489**	-0.647**	-0.382**	-0.443**	-0.656**	-0.489**	1.000									
8	-0.269*	-0.485**	-0.110	-0.279*	-0.373**	-0.384**	0.555**	1.000								
9	0.453**	0.492**	0.432**	0.356**	0.618**	0.475**	-0.536**	-0.445**	1.000							
10	0.646**	0.582**	0.503**	0.504**	0.658**	0.526**	-0.395**	-0.148	0.283*	1.000						
11	0.450**	0.595**	0.413**	0.402**	0.622**	0.484**	-0.473**	-0.067	0.325**	0.776**	1.000					
12	0.612**	0.600**	0.400**	0.539**	0.643**	0.492**	-0.678**	-0.379**	0.535**	0.504**	0.545**	1.000				
13	0.582**	0.617**	0.404**	0.498**	0.698**	0.519**	-0.715**	-0.402**	0.534**	0.536**	0.609**	0.787**	1.000			
14	0.331**	0.056	0.111	0.088	-0.039	-0.090	0.081	0.312**	-0.112	0.316**	0.103	0.055	-0.036	1.000		
15	0.325**	0.229	0.300*	0.228	0.246*	0.122	-0.020	0.162	0.023	0.365**	0.268*	0.110	0.038	0.225	1.000	
16	0.224	0.097	0.053	0.033	0.107	0.123	-0.260*	-0.308**	0.353**	-0.048	-0.079	0.330**	0.234*	-0.077	-0.563**	1.000

Df=n-2= (70); r at 5% = 0.0.232; at 1 % = 0.308; **=Significant 1% level of probability; *=Significant 5% level of probability

1. Yield kg ha^{-1}
2. Plant height at harvest
3. Number of tillers m^{-2}
4. Leaf Area Index
5. Crop dry matter
6. Crop growth rate
7. Days to 50% flowering
8. Days to maturity
9. Spike m^{-2}
10. Spike length
11. Spikelets $spike^{-1}$
12. Number of grains $spike^{-1}$
13. Weight of grains $spike^{-1}$
14. 1000 grain weight
15. Total biomass
16. Harvest index

of grains spike^{-1}. Leaf Area Index significantly correlated with crop dry matter, weight of grains spike^{-1} and harvest index but not significant with total biomass (Table 81).

4.4.2 Correlation analysis at Kadawa

The result of correlation analysis between grain yield, growth and yield components of wheat in 2014/2015, 2015/2016 and combined data in Kadawa are shown in Tables 82–84. At Kadawa, grain yield was found to be significantly and positively correlated in 2014/2015 with stand count m^{-2} (0.405**), plant height at harvest (0.402**), number of tillers m^{-2} (0.509**), leaf Area Index (0.715**), crop dry matter (0.606**), crop growth rate (0.437**), spike m^{-2} (0.542**), spike length (0.675**), spikelets spike^{-1} (0.579**), number of grains spike^{-1} (0.512**), weight of grains spike^{-1} (0.484**), total biomass (0.535**) and harvest index (0.683**). Significant but negative correlation was found between grain yield and days to 50% heading (-0.457**), days to 50% flowering (-0.484**), days to maturity (-0.515**) and sterile spikelets spike^{-1} (-0.489**). The grain yield did not significantly correlate with relative growth rate (0.126), net assimilation rate (-0.021) and 1000 grain weight (0.126). Number of tillers m^{-2} significantly and positively correlated with leaf Area Index, crop dry matter, weight of grains spike^{-1} and harvest index but not significant with total biomass. Leaf Area Index significantly correlated with crop dry matter, weight of grains spike^{-1}, total biomass and harvest index. Weight of grains spike^{-1} recorded significant correlation with total biomass and harvest index. Total biomass and harvest index also significant (0.140) correlation (Table 82).

In 2015/2016, grain yield was found to be significantly and positively correlated with stand count m^{-2} (0.347**), plant height at harvest (0.408**), number of tillers m^{-2}

Table 81: Matrix of correlation coefficient between grain yield, growth and yield components of three wheat varieties in combined analysis at Samaru

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.000															
2	-0.022	1.000														
3	0.574**	-0.089	1.000													
4	0.309**	0.537**	0.194*	1.000												
5	0.546**	0.449**	0.469**	0.543**	1.000											
6	0.330**	0.467**	0.241**	0.415**	0.798**	1.000										
7	-0.222**	-0.638**	-0.122	-0.516**	-0.617**	-0.528**	1.000									
8	-0.331**	-0.900	-0.198*	-0.103	-0.366**	-0.229**	0.327**	1.000								
9	0.212*	0.596**	0.150	0.520**	0.488**	0.372**	-0.476**	-0.231**	1.000							
10	0.339**	0.131	0.285**	0.262**	0.386**	0.368**	-0.201*	0.035	0.087	1.000						
11	0.369**	0.261**	0.342**	0.390**	0.544**	0.404**	-0.314**	-0.068	0.223**	0.623**	1.000					
12	0.434**	0.333**	0.251**	0.361**	0.565**	0.397**	-0.510**	-0331**	0.340**	0.312**	0.519**	1.000				
13	0.238**	0.578**	0.072	0.423**	0.545**	0.444**	-0.560**	-0.181**	0.434**	0.218**	0.484**	0.74**	1.000			
14	0.033	0.334**	-0.109	0.250**	0.047	0.162	-0.092	0.399**	0.093	0.114	0.078	-0.054	0.290**	1.000		
15	0.535**	-0.271**	0.417**	0.063	0.211*	0.010	0.103	-0.085	-0.095	0.221**	0.221**	0.113	-0.114	-0.091	1.000	
16	0.132	0.412**	-0.053	0.270**	0.195*	0.237**	-0.328**	-0.097	0.384**	-0.032	-0.003	0.244**	0.313**	0.167*	-0.53**	1.00

Df=n-2= (142); r at 5% = 0.0342; at 1 % = 0.1994; **=Significant 1% level of probability; *=Significant 5% level of probability

1. Yield kg ha^{-1}
2. Plant height at harvest
3. Number of tillers m^{-2}
4. Leaf Area Index
6. Crop dry matter
5. Crop growth rate
7. Days to 50% flowering
8. Days to maturity
9. Spike m^{-2}
10. Spike length
11. Spikelets $spike^{-1}$
12. Number of grains $spike^{-1}$
13. Weight of grains $spike^{-1}$
14. 1000 grain weight
15. Total biomass
16. Harvest index

Table 82: Matrix of correlation coefficient between grain yield, growth and yield components of three wheat varieties at Kadawa during 2014/2015 dry season

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.000															
2	0.402**	1.000														
3	0.509**	0.248*	1.000													
4	0.715**	0.351**	0.255*	1.000												
5	0.606**	0.395**	0.360**	0.390**	1.000											
6	0.437**	0.142	0.259*	0.202	0.795**	1.000										
7	-0.484**	-0.689**	-0.164	-0.511**	-0.430**	-0.154	1.000									
8	-0.515**	-0.437**	-0.118	-0.684**	-0.240*	-0.104	0.511**	1.000								
9	0.542**	0.509**	0.385**	0.459**	0.382**	0.243*	-0.437**	-0.405**	1.000							
10	0.675**	0.372**	0.573**	0.497**	0.642**	0.416**	-0.366**	-0.183	0.427**	1.000						
11	0.579**	0.340**	0.362**	0.496**	0.554**	0.342**	-0.325**	-0.398**	0.371**	0.614**	1.000					
12	0.512**	0.713**	0.284*	0.529**	0.321**	0.105	-0.577**	-0.512**	0.553**	0.376**	0.363**	1.000				
13	0.484**	0.664**	0.257*	0.568**	0.338**	0.105	-0.554**	-0.434**	0.590**	0.428**	0.317**	0.769**	1.000			
14	0.126	-0.038	0.214	0.043	0.263	0.280*	-0.046	0.143	-0.050	0.207	0.155	-0.191	-0.035	1.000		
15	0.535**	0.236**	0.122	0.505**	0.408**	0.249**	-0.323**	0.269*	0.442**	0.402**	0.349**	0.426**	0.457**	-0.083	1.000	
16	0.683**	0.313**	0.385**	0.464**	0.462**	0.300*	-0.356**	-0.403**	0.292*	0.488**	0.401**	0.245*	0.261*	0.175	-0.121	1.000

Df=n-2= (70); r at 5% = 0.0.232; at 1 % = 0.308; **=Significant 1% level of probability; *=Significant 5% level of probability

1. Yield kg ha^{-1}
2. Plant height at harvest
3. Number of tillers m^{-2}
4. Leaf Area Index
6. Crop dry matter
5. Crop growth rate
7. Days to 50% flowering
8. Days to maturity
9. Spike m^{-2}
10. Spike length
11. Spikelets $spike^{-1}$
12. Number of grains $spike^{-1}$
13. Weight of grains $spike^{-1}$
14. 1000 grain weight
15. Total biomass
16. Harvest index

(0.416**), leaf Area Index (0.387**), crop dry matter (0.418**), crop growth rate (0.401**), Spike m^{-2} (0.579**), number of grains $spike^{-1}$ (0.353**), weight of grains $spike^{-1}$ (0.612**), 1000 grain weight (0.582**), total biomass (0.939**) and harvest index (0.794**). Net assimilation rate (-0.252**), days to 50% heading (-0.430**), days to 50% flowering (-0.505**), days to maturity (-0.416**), sterile spikelets $spike^{-1}$ (-0.516**) were significantly correlated with grain yield. The grain yield did not significantly correlate with relative growth rate (0.066), spike length (0.181) and spikelets $spike^{-1}$ (0.082). Number of tillers m^{-2} significantly and positively correlated with crop dry matter (0.468**), weight of grains $spike^{-1}$ (0.351**), harvest index (0.373**) and total biomass (0.393**) but not significant with leaf Area Index (0.173). Leaf Area Index significantly correlated with crop dry matter (0.320**), weight of grains $spike^{-1}$(0.394**), total biomass (0.380**) but not significant with harvest index (0.205). Weight of grains $spike^{-1}$ recorded significant correlation with total biomass (0.668**) and harvest index (0.434**). Total biomass and harvest index also significant (0.140) correlation (Table 83).

In the combined mean, grain yield was found to be significantly and positively correlated with stand count m^{-2} (0.388**), number of tillers m^{-2} (0.460**), leaf Area Index (0.533**), crop dry matter (0.217**), crop growth rate (0.486**), spike m^{-2} (0.542**), Spike length (0.230**), number of grains $spike^{-1}$ (0.363**), weight of grains $spike^{-1}$ (0.508**), 1000 grain weight (0.184*), total biomass (0.833**) and harvest index (0.682**). There was also significant negative correlation between grain yield and days to 50% heading (-0.445**), days to 50% flowering (-0.518**), days to maturity (-0.405**) and sterile spikelets $spike^{-1}$ (-0.433**) while the grain yield did not significantly correlated with plant height at harvest (0.139), spikelets $spike^{-1}$ (-0.060), relative growth rate (0.002) and net assimilation rate (0.032). Number of tillers m^{-2}

significantly and positively correlated with leaf Area Index (0.240**), crop dry matter (0.243**), weight of grains spike^{-1} (0.291**), total biomass (0.292**) and harvest index (0.390**). Leaf Area Index significantly correlated with weight of grains spike^{-1} (0.373**), total biomass (0.457**) and harvest index (0.293**) but no significant correlation with crop dry matter (0.020). Crop dry matter positively correlated with weight of grains spike^{-1} (0.329**), total biomass (0.189*) and harvest index (0.315**). Weight of grains spike^{-1} recorded significant relation with total biomass (0.550**) and harvest index (0.327**). Similarly total biomass and harvest index recoded significant correlation (0.289**) (Table 84).

4.4.3 Path coefficient and percent contribution at Samaru

The path analysis shows the inter relationship of some wheat growth and yield components with grain yield. Table 85 shows the percent contribution of some wheat growth and yield component to grain yield at Samaru in 2014/2015, 2015/2016 and combined. The result in 2014/2015 indicated that the highest individual percent contribution to grain yield was obtained from total biomass of 72.70% which was followed by harvest index, LAI, weight of grain spike^{-1} crop dry matter and number of tillers m^{-2} with 14.60%, 0.05%, 0.05%, 0.03% and 0.01%, respectively. The highest positive combined contribution to grain yield ha^{-1} of 9.12% was from total biomass and harvest index. However percent contributions of crop dry matter to yield via weight of grain spike^{-1}to grain yield was negative. The percent contribution to grain yield that was unaccounted for during the analysis was 1.27%.

At Samaru in 2015/2016, it was observed that the highest individual percent contribution to grain yield of 15.53% was obtained from total biomass which was followed by 12.60%, 6.45%, 5.85%, 2.68% and 0.13% was from harvest index, weight of grain spike^{-1}, number of tillers m^{-2}, crop dry matter and LAI, respectively.

Table 83: Matrix of correlation coefficient between grain yield, growth and yield components of three wheat varieties at Kadawa during 2015/2016 dry season

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.000															
2	0.408**	1.000														
3	0.416**	0.387**	1.000													
4	0.387**	0.264*	0.173	1.000												
5	0.418**	0.682**	0.468**	0.320**	1.000											
6	0.401**	0.683**	0.452**	0.301*	0.985**	1.000										
7	-0.505**	-0.398**	-0.267*	-0.147	-0.280*	-0.270*	1.000									
8	-0.416**	-0.369**	-0.163	-0.174	-0.309**	-0.307**	0.628**	1.000								
9	0.579**	0.453**	0.405**	0.312**	0.456**	0.439**	-0.542**	-0.470**	1.000							
10	0.181	0.204	0.123	-0.095	0.103	0.077	-0.036	0.179	0.823**	1.000						
11	0.082	0.291*	0.102	-0.186	0.206	0.177	-0.163	0.100	0.067	0.823**	1.000					
12	0.353**	0.407**	0.103	0.096	0.393**	0.364**	-0.485**	-0.418**	0.416**	0.204	0.298*	1.000				
13	0.612**	0.463**	0.351**	0.394**	0.409**	0.387**	0.405**	-0.410**	0.537**	0.281*	0.221	0.342**	1.000			
14	0.582**	0.209	0.363**	0.359**	0.301*	0.267*	-0.349**	-0.199	0.445**	0.234*	0.075	0.172	0.502**	1.000		
15	0.939**	0.489**	0.373**	0.380**	0.415**	0.387**	-0.501**	-0.436**	0.576**	0.212	0.098	0.376**	0.668**	0.556**	1.000	
16	0.794**	0.181	0.393**	0.205	0.302**	0.299*	-0.475**	-0.468**	0.438**	0.068	0.045	0.317**	0.434**	0.490**	0.657**	1.000

Df=n-2= (70); r at 5% = 0.0.232; at 1 % = 0.308; **=Significant 1% level of probability; *=Significant 5% level of probability

1. Yield kg ha^{-1}
2. Plant height at harvest
3. Number of tillers m^{-2}
4. Leaf Area Index
6. Crop dry matter
5. Crop growth rate
7. Days to 50% flowering
8. Days to maturity
9. Spike m^{-2}
10. Spike length
11. Spikelets $spike^{-1}$
12. Number of grains $spike^{-1}$
13. Weight of grains $spike^{-1}$
14. 1000 grain weight
15. Total biomass
16. Harvest index

Table 84: Matrix of correlation coefficient between grain yield, growth and yield components of three wheat varieties in combined analysis at Kadawa

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.000															
2	0.139	1.000														
3	0.460**	0.176*	1.000													
4	0.533**	-0.026	0.240**	1.000												
5	0.217**	0.626**	0.243**	0.020	1.000											
6	0.486**	-0.145	0.366**	0.473**	0.091	1.000										
7	-0.518**	-0.287**	-0.244**	-0.353**	-0.165*	-0.340**	1.000									
8	-0.405**	-0.359**	-0.118	-0.302	-0.241**	-0.121	0.528**	1.000								
9	0.542**	0.352**	0.401**	0.350**	0.296**	0.301**	-0.486**	-0.429**	1.000							
10	0.230**	0.400**	0.270**	-0.039	0.500**	-0.092	-0.100	-0.018	0.217**	1.000						
11	-0.060	0.603**	0.032	-0.238**	0.664**	-0.482**	0.070	-0.190*	0.098	0.580**	1.000					
12	0.363**	0.506**	0.179*	0.189*	0.320**	0.132	-0.490**	-0.468**	0.477**	0.293**	-0.241	1.000				
13	0.508**	0.492**	0.291**	0.373**	0.329**	0.150	-0.442**	-0.422**	0.554**	0.351**	0.205	0.549**-	1.000			
14	0.184*	0.201*	0.196*	0.024	0.374**	-0.052	-0.048	0.041	0.085	0.278**	0.317**	-0.034	0.168	1.000		
15	0.833**	0.174*	0.292**	0.457	0.189*	0.399**	-0.444**	-0.334**	0.508**	0.191*	-0.056	0.361**	0.550**	0.110	1.000	
16	0.682**	0.172*	0.390**	0.293**	0.315**	0.245**	-0.405**	-0.423**	0.354**	0.256**	0.128	0.271**	0.327**	0.231**	0.289**	1.000

Df=n-2= (142); r at 5% = 0.0342; at 1 % = 0.1994; **=Significant 1% level of probability; *=Significant 5% level of probability

1. Yield kg ha^{-1}
2. Plant height at harvest
3. Number of tillers m^{-2}
4. Leaf Area Index
5. Crop dry matter
6. Crop growth rate
7. Days to 50% flowering
8. Days to maturity
9. Spike m^{-2}
10. Spike length
11. Spikelets $spike^{-1}$
12. Number of grains $spike^{-1}$
13. Weight of grains $spike^{-1}$
14. 1000 grain weight
15. Total biomass
16. Harvest index

Table 85: Percentage contribution of different growth and yield attributes to wheat grain yield in 2014/2015, 2015/2016 dry season and the combined at Samaru

Variable	**% Contribution**		
Individual contribution	2014/2015	2015/2016	combined
No. of tillers m^{-2}	0.01	5.85	5.99
LAI	0.05	0.13	0.06
Crop dry matter	0.03	2.68	3.89
Weight of grains $spike^{-1}$	0.05	6.45	0.39
Total Biomass	72.70	15.53	38.72
Harvest index	14.60	12.60	17.78
Combined Contribution			
No. of tillers m^{-2}+LAI	-0.02	0.69	-0.24
No. of tillers m^{-2}+Crop dry matter	-0.02	4.90	4.53
No. of tillers m^{-2}+Weight of grains $spike^{-1}$	0.004	4.96	0.22
No. of tillers m^{-2}+Total Biomass	-0.62	5.72	12.70
No. of tillers m^{-2}+Harvest index	-0.24	0.91	-1.09
LAI+Crop dry matter	0.05	0.64	-0.54
LAI+Weight of grains $spike^{-1}$	-0.02	0.91	-0.13
LAI+Total Biomass	1.62	0.65	-0.20
LAI+Harvest index	0.63	0.08	-0.57
Crop dry matter+Weight of grains $spike^{-1}$	-0.03	5.81	1.34
Crop dry matter+Total Biomass	1.43	3.18	5.18
Crop dry matter+Harvest index	0.50	0.38	4.49
Weight of grains $spike^{-1}$+Total Biomass	-0.92	0.76	-0.89
Weight of grains $spike^{-1}$+Harvest index	-0.20	4.22	1.65
Total Biomass+Harvest index	9.12	-15.75	-27.65
Residual	1.27	38.70	34.37
Total	100	100	100

The combined percent contribution of crop dry matter and weight of grain spike^{-1} had the highest combined percent contribution of 5.81% while the least was obtained from combined percent contribution of total biomass and harvest index (-15.75%). The unaccounted variability percent was 38.70%.

The combined mean at Samaru, indicated that the highest individual contribution of 38.72% to yield was made by total biomass followed by harvest index (17.78%), number of tillers m^{-2} (5.99%), crop dry matter (3.89%), weight of grain spike^{-1} (0.39%) and LAI (0.06%). The combined contribution of number of tillers m^{-2} and total biomass (12.70%) was the highest while the combined contributions of number of tillers m^{-2} and weight of grain spike^{-1} (0.22%) had the lowest. The combined contribution of total biomass and harvest index was negative (-27.65%) likewise a residual effect of 34.37 was unaccounted for the analysis.

4.4.4 Path coefficient and percent contribution at Kadawa

Table 86 shows the percent contribution of individual and combined contribution of some growth and yield attributes to grain yield of wheat at Kadawa in 2014/2015, 2015/2016 and the combined data. In 2014/2015, the result indicated that harvest index had made the highest contribution to grain yield (41.45 %), followed by total biomass (31.16%), number of tillers m^{-2} (3.23%), LAI (1.50%), weight of grain spike^{-1} (0.25%) and lowest individual contribution was by crop dry matter (0.02%). The combined percent contribution of number of tillers m^{-2} and harvest index (8.92%) to grain yield was the highest while the lowest was found to be combined percent contribution of total biomass and harvest index (-8.71%). The residual effect of 11.54% was unaccounted for in the analysis.

Table 86: Percentage contribution of different growth and yield attributes to wheat grain yield in 2014/2015, 2015/2016 dry season and the combined at Kadawa

Variable	**% Contribution**		
Individual contribution	2014/2015	2015/2016	combined
No. of tillers m^{-2}	3.23	0.05	0.86
LAI	1.50	0.31	0.79
Crop dry matter	0.02	0.01	0.39
Weight of grains $spike^{-1}$	0.25	0.21	0.28
Total Biomass	31.16	53.61	45.22
Harvest index	41.54	9.55	21.39
Combined Contribution			
No. of tillers m^{-2}+LAI	1.12	0.04	0.39
No. of tillers m^{-2}+Crop dry matter	-0.20	0.02	-0.28
No. of tillers m^{-2}+Weight of grains $spike^{-1}$	-0.46	-0.07	-0.28
No. of tillers m^{-2}+Total Biomass	2.45	1.24	3.63
No. of tillers m^{-2}+Harvest index	8.92	0.55	3.34
LAI+Crop dry matter	-0.14	0.04	-0.02
LAI+Weight of grains $spike^{-1}$	-0.70	-0.20	-0.35
LAI+Total Biomass	6.91	3.12	5.46
LAI+Harvest index	7.33	0.71	2.41
Crop dry matter+Weight of grains $spike^{-1}$	0.05	-0.04	0.22
Crop dry matter+Total Biomass	-0.69	0.67	-1.60
Crop dry matter+Harvest index	-0.90	0.14	-1.70
Weight of grains $spike^{-1}$+Total Biomass	-2.55	-4.48	-3.88
Weight of grains $spike^{-1}$+Harvest index	-1.68	-1.23	-1.59
Total Biomass+Harvest index	-8.71	29.74	17.98
Residual	11.54	6.00	7.35
Total	100	100	100.00

At Kadawa in 2015/2016 dry season, individual contribution of 53.61%, 9.55%, 0.31%, 0.21%, 0.05% and 0.01% were from total biomass, LAI, weight of grain spike^{-1}, number of tillers m^{-2} and crop dry matter, respectively. The combined contribution of total biomass and harvest index (29.74 %) was found to be the highest toward grain yield while the least percent contribution of the combined contribute to yield was from weight of grain spike^{-1} and total biomass (-4.48%). The unaccounted variability percent was 6.00%.

The combine result indicated that the highest individual percent contribution of 45.22% was made from total biomass while the least was obtained from weight of grain spike^{-1} (0.28%). The combined contribution of total biomass and harvest index (17.98%) was the highest while the combined contribution of weight of grain spike^{-1} and total biomass (-3.88%) was the lowest. A residual effect of 7.35% was unaccounted in the analysis.

4.4.5 Direct and indirect effect of growth and yield attributes to grain yield of wheat at Samaru

The direct and indirect effect of different growth and yield characters on grain yield in 2014/2015 dry seasons is presented in (Table 87). The greatest positive direct contribution to yield was from crop dry matter (0.4270) followed by LAI (0.3172) and the least positive contribution to grain yield was from days to 50% flowering (0.1369) while the negative direct effect was obtained from plant height (-0.0340). The highest positive indirect effect was from plant height via crop dry matter(0.2857), followed by crop dry matter via LAI (0.2554) and number of tillers m^{-2} via crop dry matter (0.0437). The least positive indirect effect to yield was through plant height via no. of tillers m^{-2} (0.0343). The indirect effect from days to 50 % flowering to other characters as well as from plant height via other characters were negative.

Table 87: The direct and indirect contribution of some growth characters and yield componentto grain yield of wheat in 2014/2015 at Samaru

	Effect through					
Characters	1	2	3	4	5	**Total correlated**
Growth characters						
1. Plant height	**-0.0340**	0.0343	0.1592	0.2857	-0.0863	0.3590
2. No. of tillers m^{-2}	-0.0107	**0.1090**	0.1116	0.1712	-0.0282	0.3530
3. Leaf Area Index	-0.0170	0.0384	**0.3172**	0.2554	-0.0629	0.5310
4. Crop dry matter	-0.0227	0.0437	0.1897	**0.4270**	-0.0867	0.5510
5. Days to 50% flowering	0.0214	-0.0225	-0.1456	-0.2703	**0.1369**	-0.2800
	1	2	3	4	5	
Yield components						
1. Spike length	**0.0002**	-0.0032	0.0000	0.1270	0.0031	0.1270
2. Weight of grains $spike^{-1}$	0.0000	**-0.0167**	0.0001	0.1788	0.0587	0.2210
3. 1000 grain weight	0.0000	0.0030	**-0.0007**	0.0941	0.0215	0.1180
4. Total biomass	0.0000	-0.0035	-0.0001	**0.8637**	0.0548	0.9150
5. Harvest index	0.0000	-0.0025	0.0000	0.1209	**0.3916**	0.5100

Bold=Direct effect

The direct and indirect effect of different yield components on grain yield showed that the greatest positive direct contribution to yield was from total biomass (0.8637) followed by harvest index (0.3916) and spike length (0.0002) while direct contributions of weight of grain spike^{-1} (-0.0167) and 1000 grain weight (-0.0007) were negative. Indirect contribution of total biomass through weight of grains spike^{-1} (0.1788) was the highest followed by weight of grain spike^{-1} via spike length (0.1270) and the least was from spike length via all parameters as well as 1000 grain weight via weight of grain spike^{-1} and harvest index via weight of grain spike^{-1}. Indirect contribution of weight of grain spike^{-1} was negative throughout.

The direct and indirect effect of different growth and yield characters on grain yield of wheat in 2015/2016 dry seasons is presented in (Table 88). The greatest positive direct contribution growth characters to was from no. of tillers m^{-2} (0.3005) followed by crop dry matter (0.2755), plant height (0.1523) and the least positive contribution to grain yield was from LAI (0.0838) while the direct effect of days to 50 % flowering was negative (-0.0578). The highest positive indirect effect was from crop dry matter via number of tillers m^{-2} (0.1856), followed by crop dry matter via plant height (0.1818) and crop dry matter via number of tillers m^{-2} (0.1703). The least positive indirect effect to yield was through number of tillers m^{-2} via days to 50 % flowering (0.0221). Indirect contributions by days to 50 % flowering was negative.

The direct and indirect effect of different yield components on grain yield showed that the greatest positive direct contribution to yield was from spike length (0.3567) followed by harvest index (0.3448) then total biomass (0.3235) and weight of grains spike^{-1} (0.2742) and the least was from 1000 grain weight (0.1570).

Table 88: The direct and indirect contribution of some growth characters and yield component to grain yield of wheat in 2015/2016 at Samaru

	Effect through					
Characters	1	2	3	4	5	**Total correlated**
Growth characters						
1. Plant height	**0.1523**	0.1403	0.0391	0.1818	0.0374	0.5510
2. No. of tillers m^{-2}	0.0711	**0.3005**	0.0330	0.1703	0.0221	0.5970
3. Leaf Area Index	0.0711	0.1184	**0.0838**	0.1490	0.0256	0.4480
4. Crop dry matter	0.1005	0.1857	0.0453	**0.2755**	0.0379	0.6450
5. Days to 50% flowering	-0.0985	-0.1148	-0.0371	-0.1807	**-0.0578**	-0.4890
	1	2	3	4	5	
Yield components						
1. Spike length	**0.3567**	0.1382	0.0496	0.1181	-0.0166	0.6460
2. Weight of grains $spike^{-1}$	0.1798	**0.2742**	0.0086	0.0356	0.1138	0.6120
3. 1000 grain weight	0.1127	0.0151	**0.1570**	0.0728	-0.0266	0.3310
4. Total biomass	0.1302	0.0302	0.0353	**0.3235**	-0.1941	0.3250
5. Harvest index	-0.0171	0.0905	-0.0121	-0.1821	**0.3448**	0.2240

Bold=Direct effect

Indirect contribution of spike length through weight of grains spike^{-1} (0.1798) was the highest followed by total biomass via spike length (0.1302) and the least positive indirect contribution to yield was from weight of grain spike^{-1} via 1000 grain weight (0.0151). Indirect contribution of harvest index was negative except with weight of grain spike^{-1}.

In the combined analysis at Samaru (Table 89), the direct and indirect effect of growth characters revealed that the greatest positive direct contribution to yield was from crop dry matter (0.4281) followed by number of tillers m^{-2} (0.3153) and the least positive contribution to grain yield was from LAI (0.1576) while the negative direct effect was obtained from plant height (-0.2825) and days to 50 % flowering (-0.0183). The highest positive indirect effect was from no. of tillers m^{-2} via crop dry matter (0.1479), followed by crop dry matter via LAI (0.0856) and LAI via number tillers m^{-2} (0.0612). The least positive indirect effect to yield was through plant height via no. of tillers m^{-2} (0.0251). Indirect effect from days to 50 % flowering was negative except with plant height.

The direct and indirect effect of different yield components on grain yield showed that the greatest positive direct contribution to yield was from total biomass (0.7393) followed by harvest index (0.4777), weight of grain spike^{-1} (0.1948), spike length (0.1283) and the least direct contributions was from 1000 grain weight (0.0164). Indirect contribution of harvest index through weight of grains spike^{-1} (0.0475) followed by spike length via weight of grain spike^{-1} (0.0400) and the least was from harvest index via 1000 grain weight (0.0027).

4.5.6 Direct and indirect effect of growth and yield attributes of wheat at Kadawa

The direct and indirect effect of different growth and yield characters on grain yield in 2014/2015 dry seasons is presented in (Table 90). The greatest positive direct

Table 89: The direct and indirect contribution of some growth characters and yield component to grain yield of wheat in combined data at Samaru

	Effect through					
Characters	1	2	3	4	5	**Total correlated**
Growth characters						
1. Plant height	**-0.2825**	-0.0281	0.0847	0.1922	0.0117	-0.0220
2. No. of tillers m^{-2}	0.0251	**0.3153**	0.0306	0.2008	0.0022	0.5740
3. Leaf Area Index	-0.1517	0.0612	**0.1576**	0.2325	0.0094	0.3090
4. Crop dry matter	-0.1268	0.1479	0.0856	**0.4281**	0.0113	0.5460
5. Days to 50% flowering	0.1802	-0.0385	-0.0813	-0.2641	**-0.0183**	-0.2220
	1	2	3	4	5	
Yield components						
1. Spike length	**0.1283**	0.0608	0.0019	0.1634	-0.0153	0.3390
2. Weight of grains $spike^{-1}$	0.0400	**0.1948**	-0.0009	0.0835	0.1166	0.4340
3. 1000 grain weight	0.0146	-0.0105	**0.0164**	-0.0673	0.0798	0.0330
4. Total biomass	0.0283	0.0220	-0.0015	**0.7393**	-0.2532	0.5350
5. Harvest index	-0.0041	0.0475	0.0027	-0.3918	**0.4777**	0.1320

Bold=Direct effect

Table 90: The direct and indirect contribution of some growth characters and yield component to grain yield of wheat in 2014/2015 at Kadawa

	Effect through					
Characters	1	2	3	4	5	**Total correlated**
Growth characters						
1. Plant height	**0.0092**	0.0660	0.1773	0.1134	0.0362	0.4020
2. No. of tillers m^{-2}	0.0023	**0.2660**	0.1288	0.1033	0.0086	0.5090
3. Leaf Area Index	0.0032	0.0678	**0.5052**	0.1119	0.0268	0.7150
4. Crop dry matter	0.0036	0.0957	0.1970	**0.2870**	0.0226	0.6060
5. Days to 50% flowering	-0.0063	-0.0436	-0.2582	-0.1234	**-0.0525**	-0.4840
	1	2	3	4	5	
Yield components						
1. Spike length	**0.0741**	0.0346	0.0114	0.2223	0.3326	0.6750
2. Weight of grains $spike^{-1}$	0.0279	**0.0920**	-0.0105	0.2356	0.1670	0.5120
3. 1000 grain weight	0.0153	-0.0176	**0.0549**	-0.0459	0.1193	0.1260
4. Total biomass	0.0298	0.0392	-0.0046	**0.5530**	-0.0825	0.5350
5. Harvest index	0.0362	0.0225	0.0096	-0.0669	**0.6816**	0.6830

Bold=Direct effect

contribution to yield was from LAI (0.5052) followed by crop dry matter (0.2870), number of tillers m^{-2} (0.2660) and the least positive contribution to grain yield was from plant height (0.0092) while the direct contribution of days to 50 % flowering (-0.0525) was negative. The highest positive indirect effect was from LAIvia crop dry matter (0.1970) and the least was no. of tillers m^{-2} via plant height (0.0023). All the indirect effect through days to 50 % flowering was found to be negative.

The greatest positive direct contribution of yield components on grain yield was from harvest index (0.6816) followed by total biomass (0.05530), weight of grain $spike^{-1}$ (0.0920), spike length (0.0741) while the least direct contributions was from 1000 grain weight (0.0549). Indirect contribution of total biomass through weight of grains $spike^{-1}$ (0.0.0392) followed by spike length via harvest index (0.0.0362) and the least was from 1000 grain weight via harvest index (0.0096).

Table 91 presents the direct and indirect effect of different growth characters and yield components on grain yield in 2015/2016 dry seasons at Kadawa. The direct effect of different growth characters showed that the greatest positive direct contribution growth characters to was from LAI (0.2513) followed by number of tillers m^{-2} (0.2075), crop dry matter (0.1105) and the least positive contribution to grain yield was from plant height (0.0405) while the direct effect of days to 50 % flowering was negative (-0.3656). The highest positive indirect effect was from no. of tillers m^{-2} via crop dry matter (0.0971) and the least was from LAIvia plant height (0.0107) while the indirect contributions of days to 50 % flowering was negative.

The direct and indirect effect of different yield components on grain yield in 2015/2016 at Kadawa showed that the greatest positive direct contribution to yield was from total biomass (0.7285) followed by harvest index (0.3077) and 1000 grain weight (0.0291)

Table 91: The direct and indirect contribution of some growth characters and yield component to grain yield of wheat in 2015/2016 at Kadawa

	Effect through					
Characters	1	2	3	4	5	**Total correlated**
Growth characters						
1. Plant height	**0.0405**	0.0803	0.0663	0.0753	0.1455	0.4080
2. No. of tillers m^{-2}	0.0157	**0.2075**	0.0435	0.0517	0.0976	0.4160
3. Leaf Area Index	0.0107	0.0359	**0.2513**	0.0354	0.0537	0.3870
4. Crop dry matter	0.0276	0.0971	0.0804	**0.1105**	0.1024	0.4180
5. Days to 50% flowering	-0.0161	-0.0554	-0.0369	-0.0309	**-0.3656**	-0.5050
	1	2	3	4	5	
Yield components						
1. Spike length	**0.0038**	-0.0050	0.0068	0.1544	0.0210	0.1810
2. Weight of grains $spike^{-1}$	0.0008	**-0.0245**	0.0050	0.2739	0.0979	0.3530
3. 1000 grain weight	0.0009	-0.0042	**0.0291**	0.4050	0.1513	0.5820
4. Total biomass	0.0008	-0.0092	0.0162	**0.7285**	0.2028	0.9390
5. Harvest index	0.0003	-0.0078	0.0142	0.4786	**0.3087**	0.7940

Bold=Direct effect

while direct contributions of weight of grains spike^{-1} (-0.0245) was negative. Indirect contribution of 1000 grain weight through harvest index (0.0142) and the least positive indirect contribution to yield was from harvest index through spike length (0.0003). Indirect contribution of weight of grains spike^{-1} was negative.

In the combined analysis at Kadawa (Table 92), the greatest positive direct contribution of growth characters to yield was from LAI (0.3453) followed by number of tiller m^{-2} (0.2737) and the least positive direct contribution to grain yield was from crop dry matter (0.1405) while the direct effect days to 50 % flowering (-0.3292) and plant height (-0.0833) were negative. The highest positive indirect effect was from no. of tillers m^{-2} via crop dry matter(0.0674), followed by LAI via no. of tillers m^{-2} (0.0666). The indirect effect of days to 50 % was negative except via plant height.

The direct and indirect effect of different yield components on grain yield showed that the greatest positive direct contribution to yield was from total biomass (0.7019) and harvest index (0.4898) while the direct contribution of spike length and weight of grains spike^{-1} were negative. Indirect contribution of total biomass through weight of grains spike^{-1} (0.2534) followed by harvest index via total biomass (0.2029) and the least was from 1000 grain weight via all other yield components. Indirect contribution of spike length was negative throughout

4.5 Partial Economic Analysis of Yield

4.5.1 Partial economic analysis of yield (Samaru)

The gross margin analysis on investment of growing wheat varieties using fertilizer and sowing method at Samaru in 2014/2015 is presented in Table 93. The result revealed that the highest return of ₦145,442.20 and a profit of ₦0.63 per naira invested was realized by application of NPK alone to drill sown wheat variety LACRIWHIT-4 and

Table 92: The direct and indirect contribution of some growth characters and yield component to grain yield of wheat in combined data at Kadawa

	Effect through					
Characters	1	2	3	4	5	**Total correlated**
Growth characters						
1. Plant height	**-0.0833**	0.0488	-0.0090	0.0880	0.0945	0.1390
2. No. of tillers m^{-2}	-0.0147	**0.2773**	0.0829	0.0341	0.0803	0.4600
3. Leaf Area Index	0.0022	0.0666	**0.3453**	0.0028	0.1162	0.5330
4. Crop dry matter	-0.0521	0.0674	0.0069	**0.1405**	0.0543	0.2170
5. Days to 50% flowering	0.0239	-0.0677	-0.1219	-0.0232	**-0.3292**	-0.5180
	1	2	3	4	5	
Yield components						
1. Spike length	**-0.0248**	-0.0046	0.0000	0.1341	0.1254	0.2300
2. Weight of grains $spike^{-1}$	-0.0073	**-0.0159**	0.0000	0.2534	0.1327	0.3630
3. 1000 grain weight	-0.0069	0.0005	**0.0000**	0.0772	0.1131	0.1840
4. Total biomass	-0.0047	-0.0057	0.0000	**0.7019**	0.1416	0.8330
5. Harvest index	-0.0064	-0.0043	0.0000	0.2029	**0.4898**	0.6820

Bold=Direct effect

Table 93: Cost benefit and return analysis on investment of growing wheat varieties using fertilizer and sowing method at Samaru in 2014/2015.

Treatments			Total Yield (kg ha^{-1})	Total variable cost (TVC) (₦)	Average price/bag (₦)	Gross revenue (GR) (₦)	Gross margin (GR-TVC) (₦)	Gross margin/naira invested (₦)
VAR	FERT	SM						
1	1	1	803.2	174500.6	15000	120480	-54020.6	-0.31
1	2	1	1748.2	235369.1	15000	262230	26860.94	0.11
1	3	1	1551.8	214470.9	15000	232770	18299.06	0.09
1	4	1	1756.6	225271.8	15000	263490	38218.22	0.17
1	1	2	803.2	167000.6	15000	120480	-46520.6	-0.28
1	2	2	1748.2	227869.1	15000	262230	34360.94	0.15
1	3	2	1551.8	206970.9	15000	232770	25799.06	0.12
1	4	2	1756.6	217771.8	15000	263490	45718.22	0.21
2	1	1	996.1	175137.1	15000	149415	-25722.1	-0.15
2	2	1	2450.9	237688	15000	367635	129947	0.55
2	3	1	1668.9	214857.4	15000	250335	35477.63	0.17
2	4	1	1915.8	225797.1	15000	287370	61572.86	0.27
2	1	2	917.7	167378.4	15000	137655	-29723.4	-0.18
2	2	2	2505.4	230367.8	15000	375810	145442.2	0.63
2	3	2	1677.8	207386.7	15000	251670	44283.26	0.21
2	4	2	2326.5	219652.5	15000	348975	129322.6	0.59
3	1	1	1148.2	175639.1	15000	172230	-3409.06	-0.02
3	2	1	2192	236833.6	15000	328800	91966.4	0.39
3	3	1	1864.9	215504.2	15000	279735	64230.83	0.30
3	4	1	1943.9	225889.9	15000	291585	65695.13	0.29
3	1	2	1187.5	168268.8	15000	178125	9856.25	0.06
3	2	2	2409.5	230051.4	15000	361425	131373.7	0.57
3	3	2	1892.9	208096.6	15000	283935	75838.43	0.36
3	4	2	1972	218482.6	15000	295800	77317.4	0.35

Calculation of total revenue is based on ₦15000 per bag (100 kg) of wheat the prevailing farm gate price at Samaru and environ
VAR=Variety: 1= LACRIWHIT-1, 2= LACRIWHIT-4, 3= LACRIWHIT-5.
SM=Sowing Method: 1=Broadcast, 2=Drill
FERT= Fertilizer :1= Control, 2= NPK, 3=FYM, 4=NPK + FYM

was followed by drill sown LACRIWHIT-4 fertilized with combined NPK and FYM with gross margin of ₦129,322.2 and a profit of ₦0.59k per naira invested and drill sown LACRIWHIT-5 fertilized with NPK alone with gross margin of ₦131,373.7 and a profit of ₦0.57k per naira invested. The least return of ₦54,020.60k loss and ₦0.31k loss per naira invested was observed by broadcasting wheat variety LACRIWHIT-1 with no fertilizer.

Table 94 shows the economic analysis of growing wheat varieties under varying sowing method and fertilizer application in 2015/2016 at Samaru. LACRIWHIT-5 sown drilled and fertilized with combined NPK and FYM resulted in gross margin return of ₦308,102.60 and a return per naira invested ₦1.34 closely followed by producing LACRIWHIT-5 using drill sowing and NPK alone with gross margin of ₦313,114.80 and a profit of ₦1.30k per naira invested while broadcast sowing of unfertilized LACRIWHIT-5 operated at loss gross margin of ₦43,741.80 and a loss of ₦0.24k per naira invested.

In the combined analysis at Samaru, gross return of ₦219,601.90k and a profit of ₦0.93 per naira invested was attained when drill sowing was employed to wheat variety LACRIWHIT-5 fertilized with NPK alone this was followed by LACRIWHIT-5 using drill sowing and fertilized with combined NPK and FYM with gross margin of ₦189,223.0k and a profit of ₦0.84k per naira invested. The least return of ₦31,454.70k loss and ₦0.18k loss per naira invested from unfertilized and broadcast sown LACRIWHIT-1 (Table 95).

4.5.2 Partial economic analysis of yield (Kadawa)

Table 96 shows the gross margin analysis on investment of growing wheat varieties using fertilizer and sowing method at Kadawa in 2014/2015. The result indicate that the highest gross return of ₦344,651.90 and a profit of ₦1.44 per naira invested was

Table 94: Cost benefit and return analysis on investment of growing wheat varieties using fertilizer and sowing method at Samaru in 2015/2016.

Treatments			Total Yield (kg ha^{-1})	Total variable cost (TVC) (₦)	Average price/bag (₦)	Gross revenue (GR) (₦)	Gross margin (GR-TVC) (₦)	Gross margin/naira invested (₦)
VAR	FERT	SM						
1	1	1	1097.1	182970.4	16000	175536	-7434.43	-0.04
1	2	1	2329.6	244787.7	16000	372736	127948.3	0.52
1	3	1	1656.4	222316.1	16000	265024	42707.88	0.19
1	4	1	2283.5	234510.6	16000	365360	130849.5	0.56
1	1	2	1143	175621.9	16000	182880	7258.1	0.04
1	2	2	2448.3	237679.4	16000	391728	154048.6	0.65
1	3	2	2410.4	217304.3	16000	385664	168359.7	0.78
1	4	2	2663.3	228263.9	16000	426128	197864.1	0.87
2	1	1	1101.5	182985	16000	176240	-6744.95	-0.04
2	2	1	2437.1	245142.4	16000	389936	144793.6	0.59
2	3	1	1836.7	222911.1	16000	293872	70960.89	0.32
2	4	1	2489.6	235190.7	16000	398336	163145.3	0.69
2	1	2	1243.3	175952.9	16000	198928	22975.11	0.13
2	2	2	2767.8	238733.7	16000	442848	204114.3	0.85
2	3	2	2058.9	216144.4	16000	329424	113279.6	0.52
2	4	2	2596	228041.8	16000	415360	187318.2	0.82
3	1	1	865.4	182205.8	16000	138464	-43741.8	-0.24
3	2	1	3177.9	247587.1	16000	508464	260876.9	1.05
3	3	1	2515.2	225150.2	16000	402432	177281.8	0.79
3	4	1	3074.2	237119.9	16000	491872	254752.1	1.07
3	1	2	1115.9	175532.5	16000	178544	3011.53	0.02
3	2	2	3463.4	241029.2	16000	554144	313114.8	1.30
3	3	2	2633.6	218040.9	16000	421376	203335.1	0.93
3	4	2	3366.8	230585.4	16000	538688	308102.6	1.34

Calculation of total revenue is based on ₦16,000 per bag (100 kg) of wheat the prevailing farm gate price at Samaru and environ
VAR=Variety: 1= LACRIWHIT-1, 2= LACRIWHIT-4, 3= LACRIWHIT-5.
SM=Sowing Method: 1=Broadcast, 2=Drill
FERT= Fertilizer :1= Control, 2= NPK, 3=FYM, 4=NPK + FYM

Table 95: Cost benefit and return analysis on investment of growing wheat varieties using fertilizer and sowing method at Samaru in combined mean.

Treatments			Total Yield (kg ha^{-1})	Total variable cost (TVC) (₦)	Average price/bag (₦)	Gross revenue (GR) (₦)	Gross margin (GR-TVC) (₦)	Gross margin/naira invested (₦)
VAR	FERT	SM						
1	1	1	950.2	178735.7	15500	147281	-31454.7	-0.18
1	2	1	2038.9	240078.4	15500	316029.5	75951.13	0.32
1	3	1	1604.1	218393.5	15500	248635.5	30241.97	0.14
1	4	1	2020	229891	15500	313100	83209	0.36
1	1	2	973.1	171311.2	15500	150830.5	-20480.7	-0.12
1	2	2	2098.3	232774.4	15500	325236.5	92462.11	0.40
1	3	2	1981.1	212137.6	15500	307070.5	94932.87	0.45
1	4	2	2210	223018	15500	342550	119532	0.54
2	1	1	1048.8	179061	15500	162564	-16497	-0.09
2	2	1	2444	241415.2	15500	378820	137404.8	0.57
2	3	1	1752.8	218884.2	15500	271684	52799.76	0.24
2	4	1	2202.7	230493.9	15500	341418.5	110924.6	0.48
2	1	2	1080.5	171665.7	15500	167477.5	-4188.15	-0.02
2	2	2	2636.6	234550.8	15500	408673	174122.2	0.74
2	3	2	1868.3	211765.4	15500	289586.5	77821.11	0.37
2	4	2	2461.3	223847.3	15500	381501.5	157654.2	0.70
3	1	1	1006.8	178922.4	15500	156054	-22868.4	-0.13
3	2	1	2684.9	242210.2	15500	416159.5	173949.3	0.72
3	3	1	2190.1	220327.3	15500	339465.5	119138.2	0.54
3	4	1	2509.1	231505	15500	388910.5	157405.5	0.68
3	1	2	1151.7	171900.6	15500	178513.5	6612.89	0.04
3	2	2	2936.4	235540.1	15500	455142	219601.9	0.93
3	3	2	2263.2	213068.6	15500	350796	137727.4	0.65
3	4	2	2669.4	224534	15500	413757	189223	0.84

Calculation of total revenue is based on ₦15500 per bag (100 kg) of wheat the average prevailing farm gate price at Samaru and environ
VAR=Variety: 1= LACRIWHIT-1, 2= LACRIWHIT-4, 3= LACRIWHIT-5.
SM=Sowing Method: 1=Broadcast, 2=Drill
FERT= Fertilizer :1= Control, 2= NPK, 3=FYM, 4=NPK + FYM

Table 96: Cost benefit and return analysis on investment of growing wheat varieties using fertilizer and sowing method at Kadawa in 2014/2015.

Treatments			Total Yield (kg ha^{-1})	Total variable cost (TVC) (₦)	Average price/bag (₦)	Gross revenue (GR) (₦)	Gross margin (GR-TVC) (₦)	Gross margin/naira invested (₦)
VAR	FERT	SM						
1	1	1	953.4	177996.2	14000	133476	-44520.2	-0.25
1	2	1	2373.5	240432.6	14000	332290	91857.45	0.38
1	3	1	2218.8	219672	14000	310632	90959.96	0.41
1	4	1	2224.2	229814.9	14000	311388	81573.14	0.35
1	1	2	1124.2	171059.9	14000	157388	-13671.9	-0.08
1	2	2	2445.9	233171.5	14000	342426	109254.5	0.47
1	3	2	2308.5	212468.1	14000	323190	110722	0.52
1	4	2	2278.9	222495.4	14000	319046	96550.63	0.43
2	1	1	1193.4	178788.2	14000	167076	-11712.2	-0.07
2	2	1	2899.1	242167	14000	405874	163707	0.68
2	3	1	2035.9	219068.5	14000	285026	65957.53	0.30
2	4	1	2617.8	231113.7	14000	366492	135378.3	0.59
2	1	2	1339.3	171769.7	14000	187502	15732.31	0.09
2	2	2	4167.9	238854.1	14000	583506	344651.9	1.44
2	3	2	2676.2	213681.5	14000	374668	160986.5	0.75
2	4	2	3234.1	225647.5	14000	452774	227126.5	1.01
3	1	1	1145	178628.5	14000	160300	-18328.5	-0.10
3	2	1	3408.4	243847.7	14000	477176	233328.3	0.96
3	3	1	2177.6	219536.1	14000	304864	85327.92	0.39
3	4	1	2673.4	231297.2	14000	374276	142978.8	0.62
3	1	2	1218.8	171372	14000	170632	-740.04	-0.004
3	2	2	3545.9	236801.5	14000	496426	259624.5	1.10
3	3	2	2530.2	213199.7	14000	354228	141028.3	0.66
3	4	2	3354.8	226045.8	14000	469672	243626.2	1.08

Calculation of total revenue is based on ₦14,000 per bag (100 kg) of wheat the prevailing farm gate price at Kadawa and environ

VAR=Variety: 1= LACRIWHIT-1, 2= LACRIWHIT-4, 3= LACRIWHIT-5.

SM=Sowing Method: 1=Broadcast, 2=Drill

FERT= Fertilizer :1= Control, 2= NPK, 3=FYM, 4=NPK + FYM

achieved by growing drill sown wheat LACRIWHIT-4 with application of NPK fertilizer alone this was followed by producing LACRIWHIT-5 using drill sowing and NPK alone with gross margin of ₦259,624.5 and a profit of ₦1.10k per naira invested as well as LACRIWHIT-5 using drill sowing and fertilized with combined NPK and FYM with gross margin of ₦243,626.2 and a profit of ₦1.08k per naira invested. The least return of ₦44,520.20k loss was observed from broadcast sown unfertilized LACRIWHIT-1.

In 2015/2016, a gross margin of ₦554,741.30 and a profit of ₦2.23 per naira invested were achieved by growing LACRIWHIT-5 drill sown and applying NPK fertilizer alone followed by drilled LACRIWHIT-5 again with combined application of NPK and FYM resulted to ₦494,142.3 gross margin and a profit of ₦2.08k per naira invested. The least return of ₦65,955.80k loss and ₦0.36k lost per naira invested (Table 97).

In the combined analysis, drilled sown wheat variety LACRIWHIT-5 fertilized with NPK alone recorded the highest gross margin of ₦399,654.30 and a profit of ₦1.62 per naira invested followed by drill sown wheat LACRIWHIT-5 with combined application of NPK and FYM fertilizer gross return of ₦362,068.90 and a profit of ₦1.54 per naira invested and drill sown wheat LACRIWHIT-4 with application of NPK alone having gross margin of ₦360.176.90 and a profit of ₦1.47k per naira invested. The least return of -₦44,246.10k and -₦0.24k per naira invested and margin of -₦32,924.3 and a profit of -₦0.18k per naira invested was recorded by growing unfertilized broadcasted LACRIWHIT-5 and LACRIWHIT-1 respectively (Table 98).

Table 97: Cost benefit and return analysis on investment of growing wheat varieties using fertilizer and sowing method at Kadawa in 2015/2016.

Treatments			Total Yield (kg ha^{-1})	Total variable cost (TVC) (₦)	Average price/bag (₦)	Gross revenue (GR) (₦)	Gross margin (GR-TVC) (₦)	Gross margin/naira invested (₦)
VAR	FERT	SM						
1	1	1	1138	185105.4	15000	170700	-14405.4	-0.08
1	2	1	3724.7	251391.5	15000	558705	307313.5	1.22
1	3	1	2248.8	226271	15000	337320	111049	0.49
1	4	1	3057.2	239063.8	15000	458580	219516.2	0.92
1	1	2	1338.1	178265.7	15000	200715	22449.27	0.13
1	2	2	4099.7	245129	15000	614955	369826	1.51
1	3	2	2687.5	220218.8	15000	403125	182906.3	0.83
1	4	2	4228.6	235429.4	15000	634290	398860.6	1.69
2	1	1	1616.9	186685.8	15000	242535	55849.23	0.30
2	2	1	3920.2	252036.7	15000	588030	335993.3	1.33
2	3	1	2301.4	226444.6	15000	345210	118765.4	0.52
2	4	1	2665.4	237770.8	15000	399810	162039.2	0.68
2	1	2	1798.1	179783.7	15000	269715	89931.27	0.50
2	2	2	4180.4	245395.3	15000	627060	381664.7	1.56
2	3	2	2392.8	219246.2	15000	358920	139673.8	0.64
2	4	2	4055.2	234857.2	15000	608280	373422.8	1.59
3	1	1	786.6	183945.8	15000	117990	-65955.8	-0.36
3	2	1	4767.5	254832.8	15000	715125	460292.3	1.81
3	3	1	2930.6	228521	15000	439590	211069	0.92
3	4	1	4672.6	244394.6	15000	700890	456495.4	1.87
3	1	2	904.7	176835.5	15000	135705	-41130.5	-0.23
3	2	2	5360.2	249288.7	15000	804030	554741.3	2.23
3	3	2	3191.3	221881.3	15000	478695	256813.7	1.16
3	4	2	4878.1	237572.7	15000	731715	494142.3	2.08

Calculation of total revenue is based on ₦15000 per bag (100 kg) of wheat the prevailing farm gate price at Kadawa and environ
VAR=Variety: 1= LACRIWHIT-1, 2= LACRIWHIT-4, 3= LACRIWHIT-5.
SM=Sowing Method: 1=Broadcast, 2=Drill
FERT= Fertilizer: 1= Control, 2= NPK, 3=FYM, 4=NPK + FYM

Table 98: Cost benefit and return analysis on investment of growing wheat varieties using fertilizer and sowing method at Kadawa in combined mean.

Treatments			Total Yield (kg ha^{-1})	Total variable cost (TVC) (₦)	Average price/bag (₦)	Gross revenue (GR) (₦)	Gross margin (GR-TVC) (₦)	Gross margin/naira invested (₦)
VAR	FERT	SM						
1	1	1	1045.7	184550.8	14500	151626.5	-32924.3	-0.18
1	2	1	3049.1	248912	14500	442119.5	193207.5	0.78
1	3	1	2233.8	225971.5	14500	323901	97929.46	0.43
1	4	1	2640.7	237439.3	14500	382901.5	145462.2	0.61
1	1	2	1231.2	177663	14500	178524	861.04	0.004
1	2	2	3272.8	242150.2	14500	474556	232405.8	0.96
1	3	2	2498	219343.4	14500	362210	142866.6	0.65
1	4	2	3253.8	231962.5	14500	471801	239838.5	1.03
2	1	1	1405.2	185737.2	14500	203754	18016.84	0.10
2	2	1	3409.7	250102	14500	494406.5	244304.5	0.98
2	3	1	2168.6	225756.4	14500	314447	88690.62	0.39
2	4	1	3141.6	239092.3	14500	455532	216439.7	0.91
2	1	2	1568.7	178776.7	14500	227461.5	48684.79	0.27
2	2	2	4174.5	245125.9	14500	605302.5	360176.7	1.47
2	3	2	2534.5	219463.9	14500	367502.5	148038.7	0.67
2	4	2	3644.7	233252.5	14500	528481.5	295229	1.27
3	1	1	965.8	184287.1	14500	140041	-44246.1	-0.24
3	2	1	4088	252340.4	14500	592760	340419.6	1.35
3	3	1	2554.1	227028.5	14500	370344.5	143316	0.63
3	4	1	3673	240845.9	14500	532585	291739.1	1.21
3	1	2	1061.7	177103.6	14500	153946.5	-23157.1	-0.13
3	2	2	4453.1	246045.2	14500	645699.5	399654.3	1.62
3	3	2	2860.8	220540.6	14500	414816	194275.4	0.88
3	4	2	4116.4	234809.1	14500	596878	362068.9	1.54

Calculation of total revenue is based on ₦14500 per bag (100 kg) of wheat the average prevailing farm gate price at Kadawa and environ
VAR=Variety: 1= LACRIWHIT-1, 2= LACRIWHIT-4, 3= LACRIWHIT-5.
SM=Sowing Method: 1=Broadcast, 2=Drill
FERT= Fertilizer :1= Control, 2= NPK, 3=FYM, 4=NPK + FYM

CHAPTER FIVE

5.0 DISCUSSION

5.1 Season and Location Effect

The performance and productivity of crops apart from their genetic constituents depends strongly on the environmental factors. These factors influenced crop growth and modify the genetic potential of plant to use them effectively. The yield potential of wheat depends on the varieties and agronomic technologies adopted to enhance yield. Wheat yield was higher in 2015/2016 than in 2014/2015 dry seasons in both locations. The lower temperature (Appendix I and II) experienced during the early growth in 2015/2016 might be one of the factors responsible for influencing higher yield. Higher values of CGR, crop dry matter and NAR could have resulted in more assimilate production and channelling to grain under low temperature. This is in line with (Kumar *et al.,* 1990) who reported that, every increase in 1^0C in minimum temperature, between 17.3 and 23.5^0C during grain development stages of wheat decreased grain yield by 176.4 kg ha^{-1}.

The general performance of wheat varieties at Kadawa was better than Samaru. The sandy loam textured soil obtainable at Kadawa experimental site provides a better growing condition for wheat. Esteban (2000) observed that wheat grows best in silt, clay and sandy loam soils. Similar results were obtained by (Ibrahim, 2016) in the same locations. At both locations the overall performance of wheat was evaluated by growth parameters such as plant height, number of tillers, number of leaves and dry matter and also yields components such as spike m^{-2}, spike length, weight of grain $spike^{-1}$, 1000 grain weight, yield and biomass. This might be as a result of favourable weather and soil conditions for the crop. Olugbemi (1990) reported the suitability of growing wheat at the study areas. There was no serious pest or disease incidence throughout the study in both years and locations.

Fertilizer application in the form of either organic, inorganic or their combination is one of the most important ways to influence soil condition. Higher crop growth and yield due to application of fertilizer could be attributed to favourable changes in soil condition which results in improvement of soil nutrients, loosening soil and enabling better root growth. Generally there was better response of wheat to NPK than FYM in this study. The high response to inorganic fertilizer over organic might be due to fast release and uptake of nutrients by the crop. However, the organic fertilizer though slow in release as mineralization had to take place before being absorbed, its effect will better be appreciated in the subsequent years since organic manure in addition to its nutrient supply, improves the physical and chemical conditions of soils due to its residual effect in the soil's fertility status (Tilahun *et al*., 2013; Redda and Abay, 2016).

5.2 Varietal Response

Generally, growth attributes such as plant height, number of tillers, number of leaves and crop dry matter varied significantly among the varieties at different sampling periods. The variety LACRIWHIT-5 was found to be superior most of the growth characters especially at Kadawa and this might be attributed to genetic variability and adaptability during the crop growth period. It could be the variety LACRIWHIT-5 had better photosynthetic efficiency due to higher leaf area index, higher solar harvesting which resulted to good growth. These findings are in line with earlier reports by Ibrahim (2016) who indicated that LACRIWHIT-5 was higher in the growth attributes than other varieties evaluated. LACRIWHIT-4 and 5 had better stand count than LACRIWHIT-1. Good establishment of crop ensures vigour and robust crop performance. Variability in stand count among wheat varieties have been reported by

(Demelash *et al*., 2014) who acknowledged that it also influence farmers choice of a variety. The difference in the height of the three varieties especially at early growth was significant in which LACRIWHIT-1 and 4 were taller than LACRIWHIT-5. This could be due to the fact that the later had prostrate growth behaviour (at Zadoks 10-30) in contrast to more erect growth of LACRIWHIT-1 and 4. This growth behaviour is ascribed to the genetic constituent of dwarfing gene inherited from ancestors. Prostrate growth habit of wheat have been reported by early researchers (Abubakar 1991) in which variety Siete cerros that was a semi dwarf exhibited such habit and is traceable to presence of dwarfing gene *Rht-B1b* (formerly *Rht1*) or *Rht-D1b* (formerly *Rht2*) which were transferred from the Japanese variety 'Norin10' into a wide range of CIMMYT germplasm (Bachir *et al*., 2013). A more recent study by Ibrahim (2016) also reported similar behaviour of LACRIWHIT-5 when compared to some wheat varieties.

LACRIWHIT-5 had higher tiller m^{-2} than the other varieties and the difference in number of tillers among wheat varieties have been reported by previous researchers, (Negedu, 1994; Abubakar, 1999) who observed the superiority of semi dwarf (Siete cerros) over Florence Aurore 8193. Ibrahim (2016) recorded higher number of tiller in LACRIWHIT-5 compared to LACRIWHIT-1 and 4; the total biomass at harvest was also higher in the former. Aykuttonke *et al.* (2011) supports the present findings, that, semi dwarf wheat cultivars had more fertile tiller than taller wheat varieties. Joppa (1983) further proved that semi dwarf wheat types had increased tillering capacity than tall genotypes.

The varieties studied differed significantly in production of effective tillers. Effective tiller is an important wheat parameter that determines yield and also evaluates the relative survival and grain bearing of the tiller. LACRIWHIT-4 and 5 had significantly higher (16.55%) effective tillers as compared to LACRIWHIT-1. Bisheshwor *et al*.

(2013) recorded significant variation in effective tillers production among wheat varieties.

The variation in number of leaves, leaf area and leaf area index varied among the varieties could have been the reason for the difference in dry matter production among the varieties as they serve as source for assimilate production. Total dry matter accumulation and partitioning is very important because it had positive relationship with absolute growth rate and crop growth rate (Amanullah and Steward, 2013; Amanullah and Muhammad, 2015). Variation in number of leaves, leaf area and LAI of wheat have been reported by (Talebifar, *et al*., 2013; Ibrahim, 2016). Jibrin and Fagam (2012) observed significantly higher leaf area in LACRIWHIT-4 than LACRIWHIT-1 but the number of leaves was similar.

The superiority of LACRIWHIT-5 in terms of CGR values at various sampling stages in LACRIWHIT-5 could be as a result of the relatively shorter height than the other varieties. This agrees with the earlier findings of (Fischer 1983; Abubakar, 1991, 1994; and Ibrahim, 2016) who reported that the shorter high yielding genotypes show high CGR than tall low yielding ones.

Earliness to heading, flowering and maturity by LACRIWHIT-1 and 4 compared to LACRIWHIT-5 and the outstanding performance of LACRIWHIT-5 in grain yield higher than the former is not surprising, a variety that stays longer in field records longer leaf area duration (LAD) hence longer period for assimilate production and subsequent translation to yield. Similar result was obtained by (Ibrahim, 2016). Demelash *et al*. (2014) also observed dissimilarity on days to heading, flowering and maturity among wheat varieties and attributed it to their genetic makeup.

The high grain yield of LACRIWHIT-5 could be due to its inherent genetic composition as influenced by the favourable environmental factors that allowed the crop to grow and yield coupled with its heat tolerant ability. This was evident from the higher values of number of leaves, leaf area, number of tillers, 1000-grain weight as well as total biomass and harvest index in LACRIWHIT-5 compared to LACRIWHIT-1 and 4. It is also apparent that even at high temperature of maximum and minimum: $34.9^0C/16^0C$, $34.6^0C/18.2^0C$ and $31.6^0C/15^0C$ in 2014/2015 and $34.9^0C/16^0C$, $34.6^0C/18.2^0C$ and $31.6^0C/15^0C$ in 2015/2016 at Kadawa in February (Appendix II), the performance LACRIWHIT-5 was still superior to the other varieties.

Late maturing varieties are known to yield higher because the longer the crop stays under normal condition the more assimilates produced and translocated to grain. In Nigeria, solar radiation is a limiting factor due to the harmattan dust that settles on the leaves, thus preventing photosynthesis. A variety that stays longer on the field therefore optimizes the use of the resources for high grain production. This was further supported by the fact that LACRIWHIT-5 had longer effective grain filling period. Grain filling depends on the post anthesis photosynthesis of the flag leaf. Wardlaw (1970) reported that almost all assimilates produced after anthesis is partitioned to the grain, although evidence of mobilization of the stored carbohydrate to the stem exists.

Furthermore, the superiority of LACRIWHIT-5 was realized due to the fact that yield components such as 1000-grain weight and biomass were higher compared to that of LACRIWHIT-1 and 4 at both locations. The strong positive correlation of 1000-grain weight and biomass to grain yield further buttress the discussion. These results are in agreement with the findings of (Ibrahim, 2016) who reported that LACRIWHIT-5 yielded more when compared with other varieties evaluated. In addition, the higher biomass of LACRIWHIT-5 compared to LACRIWHIT-1 and 4 which were relatively taller might be due to the fact that the shorter variety matures later then the taller, hence utilize longer photosynthetic days. This view was earlier shared by Waddington *et al*.

(1986) who postulated that a higher biomass is associated with longer duration genotypes. Such performance was confirmed by Abubakar (1999) at Kadawa and by and Ibrahim (2016) at Kadawa and Samaru. Similarity of LACRIWHIT-1 and 4 on biomass production was also reported by Jibrin and Fagam (2012) at Bauchi.

LACRIWHIT-5 had the highest harvest index at Kadawa. Harvest index measures the stability of the variety to channel assimilates to grain production at expense of straw. It has further confirmed the superiority of the variety because it proves more efficient in channelling assimilates to grain at expense of straw. Varietal variation on harvest index was obtained by Abubakar (1999); Onyibe (2005); Ibrahim (2016). It was also observed that LACRIWHIT-5 had more sterile spikelets than other varieties. Though sterility is ascribed to high temperature (Smika and Shawcroft, 1980), LACRIWHIT-5 is heat tolerant therefore the exhibition of sterile spikelets by LACRIWHIT-5 in this study could be due to its sensitivity to poor nutrition as high sterility was observed more in the unfertilized plots of LACRIWHIT-5. This is in line with (Abbate *et al*., 2013) who established that floret survival is achieved by avoiding carbon, water and nutrient (particularly N) limitations.

One of the yield components that determines yield is the 1000 grain weight, it is a genetically governed character (Abubakar, 1991) and significantly higher values were recorded for LACRIWHIT-5. Demelash *et al*. (2014) recorded difference in 1000 grain weight among wheat varieties.

Other components such as: spike length and weight of grain spike^{-1} were also higher in LACRIWHIT-5. The superiority of LACRIWHIT-5 over other varieties can be obviously associated to the reasons of genetic composition, adaptability, heat tolerance and better tolerance to environmental resources. LACRIWHIT-5 is a newly released variety as such it is expected since elite varieties are mostly improvement over the existing ones. Other yield components such as number of grain spike^{-1} which was low in LACRIWHIT-5 might have been compensated by high 1000 and individual grain weight which was evident from even the physical seed size. Compensation for yield component is a common occurrence in wheat. Stapper and Fischer (1991) observed higher grain number was associated with low grain weight and vice versa both within and between genotypes. These were confirmed by (Abubakar (1999); Onyibe (2000); Sokoto and Singh (2013); Ibrahim (2016).

Variability among varieties in proximate and gluten content analysis has been observed in the study. Variation in moisture content could be attributed to moisture retention of relatively carbohydrate –rich endosperm of LACRIWHIT-5 and 4. Similarly, lipid and carbohydrate content were found to be higher in LACRIWHIT-5. Variation in moisture, lipid and carbohydrate among wheat varieties have been reported by (Sameen *et al*., 2002).

LACRIWHIT-4 and 5 have shown consistently lower grain protein concentration than LACRIWHIT-1. This appears to primarily be as a result of high yield potential and subsequent dilution of protein. LACRIWHIT-4 and 5 have larger grain size which allows for more endosperm content as shown by their carbohydrate contents. Dilution of wheat grain protein in varieties with high yield potential have been observed by Brill *et al*. (2017). High concentration of protein and gluten in LACRIWHIT-1 might also be due to early maturity of the variety which allows for escape of high temperature during grain filling period. This is in line with Nuttall *et al*. (2017) who reported high temperature during grain filling affects grain protein and gluten content. Previous researchers (Abubakar, 1991; Kaur *et al*., 2015; Brill *et al*., 2017) have reported variability in protein and gluten content among wheat varieties.

5.3 Response to Sowing Method

Growth parameters such as stand count, number of tillers, number of leaves, leaf area, dry matter, CGR, RGR, NAR and days to maturity were affected by sowing method and mostly favouring drill sowing than broadcast. This might be due to the advantages enjoyed by drill sown wheat such as uniform germination, better light interception for photosynthesis and transportation of assimilates for dry matter production and effective utilization in tillering and grain filling. Higher emergence recorded by drill sown wheat could be due to the sowing at optimum and uniform depth, whereas broadcasting resulted in poor wheat emergence which might be due uneven placement of seed. Poor wheat emergence in broadcasting as compared to drill sowing was also reported by Ali *et al*. (2012); Amin *et al.* (2013a). However, at Samaru statistically similar stand count was recorded in both sowing methods and might be attributed to the soil type that offered similar conditions for the germination of the crop and this is in line with Abbas *et al*. (2009) who concluded that seed germination was statistically similar in both sowing methods of wheat and it might be attributed to soil conditions which played major role in germination of the crop.

At Kadawa in 2015/2016, broadcast produced taller plants than drilled and may be due to plant competition as broadcasting left uneven space where as drilling provided uniform space as observed by Ansari *et al*. (2006); Chachar *et al*. (2009); Soomro *et al*. (2009). However, significant difference was not observed with regards to sowing methods at Samaru. The similarity of plant height in both sowing methods could be ascribed to the appropriate plant population and inherent varietal character of wheat varieties used. Similar result was reported by Ata-Ul-Karim *et al*. (2015) and Naresh *et al*. (2014) using wheat variety PBW-343. But contrary to Khan *et al*. (2007); Soomro *et* *al*. (2009); Abbas *et al*. (2009); Nasrullah *et al*. (2010); Safdar *et al*. (2011) and Ali *et al*. (2012) who observed taller plant in drill sown wheat than broadcasted.

Tiller production was significantly affected by sowing method in which drill sown wheat had more tillers than those broadcasted. This could be due to the fact that the individual plants had enough space to produce more tillers. Higher tiller production in drill sowing over broadcast was reported by (Soomro *et al*., 2009; Ali *et al*., 2012; Amin *et al*., 2013a; Ata-Ul-Karim *et al*., 2015; Ayalew *et al*., 2017). Same trend was observed with respect to dry matter production. However, Abbas *et al*. (2009) did not record significant difference in tiller production between the sowing methods.

The difference in grain yield due to sowing method was significant, with drill having higher yield than broadcast. Grain yield is the result of all considered yield components such as effective tillers per unit area, number of spike m^{-2}, number of grains per spike, and grain weight. These were significantly affected and the drilled wheat was favoured over broadcast. Yield and yield components are traits that are determined by photosynthetic activities after anthesis. Although some yield components such as spike m^{-2} and number of grains per spike are predetermined at the vegetative stage of spike primordia formation.

The superiority of drilled wheat in terms of yield components could be attributed to better stand establishment, light interception for dry matter production, tillering and spike formation. Higher values for biomass and harvest index were recorded in drill compared to broadcast, the superiority of drill over broadcast in biomass production could be due to high tiller and biomass production, similar result have been reported by Amin *et al*. (2013b).

The similarity in yield components such as number of grains per spike and 1000-grains weight could be as a result of variation in sowing method. These traits are determined mainly by genetics (Abubakar, 1991) and therefore generally are not affected as much by environmental conditions (Safdar *et al*., 2011). On the other hand, the high number of tillers per unit area recorded under drill sown wheat than broadcasted ones could be due to availability of enough space which reduced competition for moisture, space and nutrients among the wheat plants and hence more tillers and spikes recorded in the drill sown wheat. Similar findings were also reported by (Ata-Ul-Karim *et al*., 2015; Naresh *et al*., 2014; Bisheshwor *et al*., 2013; Bruns, 2011; Steckel and Gwathmey, 2009; Wrather *et al*., 2008). The findings reported by Nasrullah *et al*. (2010) and Abbas *et al*. (2009) contradicts the present findings and this might be due to varying environmental and soil conditions.

The lack of significant effect of sowing method on ash, fibre, lipid, protein and carbohydrate contents in the proximate analysis could be that the variability in the crop environment due sowing method is negligible as regard these components. Although broadcasting is expected to retain moisture, spacing of 30 cm could have produce more foliage and conserve moisture, hence higher grain moisture content in the drilled sown wheat. Gluten content was also found to be higher in 2014/2015 at Samaru and could be due to better nitrogen and phosphorus utilization in the drill sown plots.

5.4 Response to Fertilizer.

The significant variation recorded in terms of growth parameters such as plant height, number of tillers, number of leaves, dry matter, crop growth rate, days to 50% heading, flowering and maturity as a result of use of NPK, FYM or their combination. These are expected considering the positive role fertilizers play on growth and development of crops particularly if applied on soils with low fertility as was the characteristics of the experimental soil (Table 1). It was generally observed that higher response to fertilization was recorded with the application of NPK alone and this could be due to fast release and easy absorption of mineral fertilizer. Organic (FYM) fertilizers are slow in release even when combined with inorganic and their effects are cumulative hence the overall effects are noticed in the subsequent years when the manures fully mineralized and soil amended. This is in line with the finding of Desai *et al*. (2015); Zeid*et al*. (2015) and Abdelgadir *et al*. (2016).

Application of fertilizer influenced stand count which might be as a result of availability of more nutrients such as nitrogen, phosphorus and potassium as well as enhancement of water holding capacity of the soil. Moisture and nutrients are important factors governing stand establishment. Significant influence of fertilizer on stand count of wheat has been reported by Muhammad *et al*. (2014), Mueen-ud-din *et al*. (2015) and Akbari and Ghosh (2016) who attributed better stand establishment to availability of nutrients to the growing seedlings. Nitrogen and phosphorus availability are critical such that varying the quantity applied affects stand count. Asargrew *et al*. (2014) obtained the highest stand count with the application of nitrogen and phosphorus (N /P_2O_5) at 276/90 kg ha^{-1}.

The taller wheat plants height obtained as a result of application of NPK alone or in combination with FYM may be due to enhancement of soil fertility by the fertilizer applied the soil which has low fertility (Appendix 1). N, P and K nutrition play stronger role in cell division; cell expansion and enlargement which ultimately affect the vegetative growth of wheat plant particularly plant height. Mueen-ud-din *et al*. (2015) comparing various farmyard manure treatments found that plant height increased significantly over the control. Significant influence of N, P and K fertilizers on height of wheat are reported by other researchers (Bakht*et al*. (2010); Laghari *et al*. (2010); Muhammad *et al*. (2014); Kousar *et al*. (2015); Abebe and Manchore (2016) and attributed the increase in plant height to more availability of nutrients especially N, P and K which might have increased the cell division phenomena and thus taller plants produced.

Crop yield depends upon many yield contributing components among which tiller number is paramount. Tiller production, either per plant or per unit area, is an important character as it affects the yield potentialities of wheat varieties (Miko 1991). It is worth mentioning, however, that tillering capacity is genetically controlled, but much influenced by environmental factors. Short day condition associated with high light intensity and low temperature as observed during the growing period (Appendix I and II) coupled with good nutrient supply favoured tillering. This explains the high tiller in the fertilized plots than control treatment. High tiller production as a result of nutrient supply is reported by Miko (1991); Abubakar (1999); Bakth *et al*. (2010); Muhammad *et al*. (2014); Mueen-ud-din *et al*. (2015); Abebe and Manchore (2016). Similarly, higher leaf area and leaf area index where observed with application of NPK or FYM hence more source for high assimilate production which directly translates in to dry matter. This corroborates study of (Bakht *et al*., 2010 and Muhammad *et al*., 2014).

Fertilizer application as earlier noted increases tiller production, which directly influences leaf number and LAI of the crop. The reduction in leaf area and LAI after the third sampling (Zadoks 50-60) when the crop start heading might be due to channelling of most of the assimilates produced were directed toward grain filling process at the expense of vegetative growth.

Larger leaf area observed with fertilized plots means more photosynthetic surface for assimilate production and consequently higher dry matter for enhanced crop growth rate. Laghari *et al*. (2010) observed application of 120, 60 and 60 N, P and K kg ha^{-1} respectively significantly increased dry matter production in wheat. Similarly, Jamilu and Samina (2013) reported increase shoot dry biomass by 80% and 137% at the flowering and maturity stages, respectively with the application NPK. Amanullah and Muhammad (2015) observed that increase in P level resulted in accumulation of more total dry matter and portioned more to spike at both anthesis and physiological maturity. This could The increase in total dry matter accumulation with increase in P might be due P being the components of ATP and contributed to a higher photosynthetic rate, abundant vegetative growth and assimilates formation and partitioning.

Days to 50 % heading, flowering and maturity were relatively earlier in the fertilized plots compared to the unfertilized ones. These might be due to wheat supplied with adequate nitrogen, phosphorus and potassium fertilizers grows rapidly and produces large amounts of succulent, green foliage then head, flower and mature. This agrees with Laghari *et al*. (2010) who reported application of 120, 60 and 60 N, P and K kg ha^{-1} respectively significantly shortened maturity days of wheat.

Zerihun (2016) observed that in sorghum, providing adequate nitrogen allows crop to grow to full maturity, rather than delaying. It might also be attributed to the role of P in conjunction with N and K in dry matter production and distribution which facilitates plant development. In addition, P is vital to plant growth and is found in every living plant cell. It is involved in several key plant functions, including energy transfer, photosynthesis, transformation of sugars and starches, and nutrient movement within the plant. Ahn (1993) indicated that P is concentrated in the fast growing parts of the plant and, therefore, it hastens the maturing period of crops. The concentrations of N and P in the soils of both locations were low (Table 1), and this might result in late heading and maturity. (Anon, 1999) reported that slow growth, reduced tillering, late maturity and reduced yields are characteristics of phosphorus deficient wheat. Delay in blooming and maturity due to Phosphorus deficiency is reported in other crops; in cowpea (Sison and Margate, 1981), rice Tilahun *et al*. (2013), barley (Wakene *et al*., 2014). Also, Ottman (2009) observed that increase in P rate decreased time to heading, anthesis and maturity in wheat and barley.

Impliedly, adequate fertilization of wheat results in early maturity hence escaping terminal heat stress which is a common occurrence in the wheat growing regions of Nigeria. Therefore, the use of FYM and inorganic NPK fertilizers in the production of wheat could be used as a strategy to enable the crop to escape terminal heat stress. Report of Wonprasaida *et al*. (2006) also observed variation days to maturity in wheat as result of application of combined FYM and NPK fertilizer application.

Information on N effects on flowering time is highly dispersed in the literature, and even when those effects were large, researchers have often noted them in passing, without attempting to consider the subject in a broader context or trying to link the effects with some indicator of crop nitrogen response (Hall *et al*., 2014). It has been argued, from the viewpoint of evolutionary ecology (Pierce *et al*., 2005), that plastic responses of development in annual species to stress, including both water and nutrient stresses, could improve ecotype fitness (i.e., the ability to contribute the next generation). In this context, the expected response to a restriction in resource availability is an increase in the rate of development, which translates into a reduced time to flowering and a shorter overall life cycle. Attempts to demonstrate the existence of a response of this nature in several species have revealed a rather more complex picture. Lengthening (Pigliucci and Byrd, 1998; Volis *et al*., 2002) and shortening (Pigliucci and Schlichting, 1995; Kolar and Senkova, 2008) in duration of the germination to bolting phase in some Arabidopsis thaliana ecotypes under low N and slow-release N–P–K fertiliser have been observed. The responses of development to N in cultivated species appear to be equally varied.

Effect of N fertilizer on flowering time of wheat and barley has been extensively reviewed by Hall *et al*. (2014), using crop yield responses as a proxy for crop nitrogen status. Volume of experiments in which both variables (time to flowering and yield) have been recorded. Given conflicting reports about the effects of nitrogen on development (slowing or accelerating rates of development), they were particularly interested in trying to establish whether there was a consistent pattern of flowering time response to nitrogen in these cereals. They also sought to test the ideas of Angus and Moncur (1985) and Williams and Angus (1994) who, in the only detailed published model proposed for these responses in wheat, suggested a non-linear response of flowering time to N application. A response function of this form might explain why in some cases (highly N-stressed controls) there is a developmental response while in others (mildly to moderately N-stressed controls) phenology is largely unaffected by fertilisation. A further feature of analysis that they used the relative (to unfertilised control) response of yield to nitrogen (rather than relative N content of the crop or the rate of N fertilisation) as a rough proxy for the degree of N-stress the unfertilised crop was subjected.

In controlled environmental conditions, and for wheat, Angus and Moncur (1985) reported a slight acceleration of rate of development when plants were subjected to low levels of N in the nutrient solution after floral initiation, and Nerson *et al*. (1990) found that 85 ppm of N in the nutrient solution shortened the time to terminal spikelet initiation (with respect to 5 ppm N) by between 16 and 22 days, depending on the levels of P in the solution. Similar scenario was observed in the present study as the soil was low in N and P (Appendix 1), nutrients supplied by NPK and FYM applied might hasten heading and flowering of the fertilized plots.

Yield components such as spike length, spike m^{-2}, 1000-grain weight, grain per spike and higher biomass yield of wheat were influenced by fertilizer application, this is because an increase in fertilizer application especially NPK positively enhances chlorophyll content in plants thereby providing photosynthetic activities that promote assimilate production and result in the final yield.

From the study, highest yield was obtained with the application of NPK alone or in combination with FYM as well as FYM alone and the least was in the unfertilized control. This is in line with the result of this study of Gomaa *et al*. (2015), Kousar *et al*. (2015), Abdur *et al*. (2016) andAbebe and Manchore (2016) reported highly significant influence of NPK fertilizer on grain yield of wheat. Mueen-ud-din *et al*. (2015)also recorded high yield of wheat as a result of application of FYM. This is because of well-balanced supply of NPK at optimal amount, results in higher net assimilation rate and increased grain yield. The increase in yield due to the application of nutrients through FYM alone or in combination with NPK might be due to higher availability of nitrogen phosphorus and potassium to plants, besides increased water holding capacity and other physical, chemical and biological properties of soil and due to the influence of growth promoting substances.

Longer spike, more spike m^{-2}, higher 1000-grain weight, more grain per spike and higher biomass yield of wheat was achieved by application NPK alone or combined with FYM compared to the control. This is expected because nutrients are utilized for effective production of yield components. Similar results were reported by Laghari *et al*. (2010); Kousar *et al*. (2015); Mueen-ud-din *et al*. (2015);Abdur *et al*. (2016); Abebe and Manchore (2016). However, in contrast to the finding of this study, (Melesse, 2007) reported no significant effect of application of NPK fertilizer on thousand seed weight of bread wheat.

Fertilizer application was found to enhance grain moisture, lipid protein and carbohydrate and this could be attributed to promotion of grain constituents by adequate nutrition. Similar result was obtained by (Sameen *et al*., 2002) in which high moisture, protein and ash content were observed under NPK fertilized wheat. However, they observed non significant effect on lipid content which is contrary to the present study in which high ash and lipid content were observed in the unfertilized plots. Abubakar (1992) and Abedi *et al*. (2010) reported significant increase in grain protein by NPK and FYM respectively. Similarly, gluten content of wheat increased with application of NPK alone or in combination with FYM. Gluten constitutes major part of wheat grain protein (Kucek *et al*. 2015), NPK are known in protein synthesis and formation of nucleoprotein and DNA, therefore, the supply of NPK alone or in combination with FYM influence grain protein and ultimately affect gluten content. Similar results were observed by Abubakar (1992) and Gomaa *et al*. (2015).

5.5 Interactions

5.5.1 Variety and sowing method

Variety and sowing method interaction on stand count, leaf area index, crop dry matter, net assimilation rate, effective tillers and grain yield revealed that wheat varieties reacted diversely to sowing method mostly favouring drill sowing in all the varieties for most parameters. This could be attributed to the fact that drilled wheat had better growth and development due to the fact that air, space, nutrient, water and weed management are enhanced with drill sowing. This allows for photosynthetic efficiency and production of more assimilates for dry matter production which translates to yield.

The high stand count at Samaru in LACRIWHIT-4 and LACRIWHIT-5 under drill sowing might be due to favourable germination and rooting under drill sowing. While at Kadawa the similar response of LACRIWHIT-4 to both sowing methods could be that the soil condition under both sowing methods was adequate for optimum germination and rooting. Ali *et al*. (2012) and Amin *et al*. (2013a) observed that drill sowing allow for better germination due to the sowing at optimum and uniform depth. The high LAI in drill sown LACRIWHIT-5 followed by drilled LACRIWHIT-4 and LACRIWHIT-1 might allowed for maximum interception of solar radiation for photosynthesis and dry matter production and growth and yield components such as grown root initiation and spike formation. The high spike m^{-2} in drilled LACRIWHIT-5 might have contributed to the high grain yield. Ata-Ul-Karim *et al*. (2015) and Naresh *et al*. (2014) corroborated this finding while Nasrullah *et al*. (2010) and Abbas *et al*. (2009) negate this, which might be due to varying environmental and soil conditions. Regardless of the sowing methods, LACRIWHIT-5 recorded the highest value for carbohydrate and lipid content. This could be due to the ability of the variety to produce higher grain yield which is always associated with high carbohydrate and low protein content.

5.5.2 Variety and fertilizer

The significant interaction between varietyand fertilizer on plant height, number of leaves, leaf area, leaf area index, crop dry matter, CGR, RGR, NAR, days to 50% heading, days to 50% flowering, days to maturity, effective grain filling period, biomass, harvest index and grain yield could be as a result of fertilization improving the performance in all the varieties thus indicating the important role played by fertilizer in growth and development wheat through increase in meristematic and physiological activities of the crop. Application of NPK alone or combination with FYM generally improved the above mentioned growth and yield and yield components in all the varieties. Taller plants were produced when LACRIWHIT-4 or LACRIWHIT-1 varieties were fertilized with NPK alone or combined with FYM than LACRIWHIT-5 but better response was observed in LACRIWHIT-1. Nutrient release is faster in inorganic fertilizers and difference in varietal response could be genetic. Number of leaves, leaf area, leaf area index were better developed with application of NPK alone or combined with FYM to LACRIWHIT-4 and LACRIWHIT-5 followed by LACRIWHIT-1. Similarly significant interaction was observed on CGR and RGR at 6-9 and 9-12 WAS. Application of NPK alone or combined with FYM produced higher CGR and RGR than in the FYM alone and control plots. LACRIWHIT-1 and LACRIWHIT-5 proved superior over LACRIWHIT-4. At both Samaru and Kadawa, heading, flowering and maturity were early when NPK alone or combined with FYM to LACRIWHIT-1 and LACRIWHIT-4. The delay in heading, flowering and maturity of of LACRIWHIT-5 when no fertilizer was applied could be due to requirement of adequate nutrition by wheat plants to complete physiological development. Lack of NPK fertilization slows growth and rate of photosynthesis crops. Abebe and Manchore (2016) corroborate this finding. Therefore, early establishment of wheat under low fertilizer resource is suggested to coincide growth stages such as booting and flowering with low temperature period to maximize utilization.

The superiority of LACRIWHIT-5 it received NPK alone or combined with FYM in grain yield followed by LACRIWHIT-4 and 1 could be improvement of soil fertility and genetics of LACRIWHIT-5 which ensured higher LAI for assimilate production and more spikes and heavier grains. On the other hand, LACRIWHIT-5 LACRIWHIT-4 produced highest grain yield when NPK alone was applied while unfertilized plots produced least grain yield in all the varieties and this might be due to fast release of nutrients in mineral fertilizers compared to organic fertilizers. This is in line with (Abebe and Manchore, 2016 andMueen-ud-din *et al*., 2015).

5.5.3 Sowing method and fertilizer

The significant interaction of sowing method and fertilizer on stand count, plant height, LA, crop dry matter, CGR, RGR, NAR, days to 50% heading, days to 50% flowering, days to maturity, effective grain filling period and spike m^{-2} which in most cases the drill sowing and fertilized with NPK alone were superior. The drill sowing ensured little competition for limiting soil resources of water and nutrient and environmental factors of solar radiation and space. However, broadcast sown wheat also enjoyed similar condition as such taller plants were recorded in broadcasted wheat fertilized with NPK alone. Similarly, regardless of sowing method higher dry matter were produced with application of NPK alone and this could be due to fast release of nutrients by the mineral fertilizer enhanced by spacing and less population pressure under drill sowing. High dry matter produced is used in the development of yield structures such as spike. Highest spike m^{-2} was produce in drill sowing fertilized with NPK alone or combined with FYM. Under both sowing methods, wheat supplied with NPK alone or combined with FYM resulted to higher growth, yield component and yield. This is as a result of well-balanced supply of N, P and K with application of NPK alone (Abebe and Manchore, 2016), not only supply nutrients but when combined with FYM influence physical properties such as water holding capacity and chemical properties as well as biological properties of soil (Mueen-ud-din *et al*., 2015).

5.6 Correlation and Path Coefficient Analysis

The significant and positive correlation observed between grain yield and most growth and yield components of wheat such as plant height, number of tillers m^{-2}, LAI, crop dry matter, CGR, spike m^{-2}, spike length, number of spikelets $spike^{-1}$, number of grains $spike^{-1}$, weight of grains $spike^{-1}$, 1000 grain weight, total biomass and harvest index is important. This shows that there is interdependency within and between characters and greatly determine the grain yield directly or otherwise. Previous researher (Ibrahim 2016; Mohammadi *et al.*, 2016; Bagrei and Bybordi, 2015;Poor *et al*. 2015; Onyibe 2000; Abubakar 1999) also observe the same.

Positive correlation between plant height as well as LAI with grain yield implies that height and LAI facilitate interception of solar radiation by assimilatory organs for effective photosynthesis which form the basis for growth through dry matter production and subsequent yield increase. This result correspond with the findings of many investigators (Khan *et al.*, 2013a; Fellahi *et al.*,2013; Chhibber *et al*., 2014). Also, significant positive correlation of LAI to CGR and RGR could be as a result of larger leaf area. The higher the LAI the more photosynthetic area for light interception and consequently improved photosynthetic activities for higher growth rate.

The negative relationship between grain yield and days to 50% flowering and maturity indicated that shorter the days to flowering the higher the yield. This allows for longer grain filling period. However, negative correlation with maturity call for breeding for early maturing with effective photosynthetic mechanism and adequate sink to utilized the assimilates being produced. Khan *et al*. (2013b) similarly observed negative correlation of grain yield to days to 50% flowering and maturity. Also, the negative correlation between number of grains spike^{-1} and 1000 grain weight shows that the fewer the grain spike^{-2} the heavier the average 1000 grain weight and vice versa. The fewer grains are thus compensated by larger and heavier grains produced. Compensation mechanism in wheat has been reported by (Ibrahim 2016; Abubakar 1999; Onyibe 2000). The positive correlation between grain yield and spike m^{-2}, number of grain spike^{-1}, weight of grains spike^{-1} and 1000 grain weight showed these parameters as important yield determinants. This result confirms the findings of (Ibrahim 2016; Abubakar 1999; Onyibe 2000).

In the path coefficient analysis, total biomass production had both the greatest direct effect and total contribution to grain yield. This is expected because the larger the biomass the more the photosynthetic area for dry matter production and hence the higher the yield. This was followed by harvest index indicating better partitioning of photosynthates to the grain. Therefore, the more the grains per given biomass the more the yield. Similar results were observed by (Bagrei and Bybordi, 2015; Maleki *et al*. 2008). The highest positive indirect effect from crop dry matter via weight of grain spike^{-1} as well as number of tillers m^{-2} via total biomass at Samaru and from weight of grain spike^{-1} via total biomass at Kadawa probably signify interdependence of growth and yield components as well as among yield components to the grain yield.

The high direct effect exhibited by yield component used for the analysis throughout the years of study and the combined and the low residual values obtained in study suggest that the major characters contributing to the grain yield of wheat were measured. It was realized that only 1.2%, 38.70% and 34.37% and 11.54%, 6.0% and 7.35% of the variability remain unaccounted at Samaru and Kadawa in 2014/2015, 2015/2016 and their combined mean respectively.

5.7 Cost benefit analysis

The economic analysis of this study revealed that, regardless of variety, application of NPK alone or combined NPK and FYM to drilled wheat increased grain yield. In the combined analysis at both locations application of NPK alone to drill LACRIWHIT-5 resulted in the highest gross margin and profit per Naira invested followed by application of combined NPK and FYM to drilled LACRIWHIT-5. The lowest gross margin came from broadcast sown unfertilized LACRIWHIT-1 followed by LACRIWHIT-5 under same treatment. This might be an indication of wheat requiring adequate nutrition for vegetative and reproductive development and the superiority of drill sowing in the management of irrigated wheat. Yield obtained in all the varieties under no fertilizer and broadcast sowing might not be abundant enough to upset the cost incurred for irrigation and other management practices of production. This shows that for profitable production of wheat, there is need for soil fertility improvement through organic, inorganic or their combination to enhance grain yield. This is in line with (Olugbemi, 1994) who reported low soil fertility as one of the production constrains of wheat.

Though application of NPK alone resulted in higher economic return, combined application of NPK and FYM seem sustainable in wheat production as the yield differences was marginal. This coupled with the numerous benefits of FYM in the soil as highlighted by (Boru *et al*., 2017), adopting fertility improvement practices such as fertilizer application ensures proceeds of wheat production in the Sudan and Northern Guinea Savanna of Nigeria.

CHAPTER SIX

6.0 SUMMARY AND CONCLUSION

Experiment was conducted in 2014/2015 and 2015/2016 dry seasons at the Institute for Agricultural Research Farm, Samaru (11°11'N, 07°38'E, 686m above sea level) and the Irrigation Research Station, Kadawa ($11^0$39'N, $08^0$27'E; 500m above sea level) of the Institute for Agricultural Research, Ahmadu Bello University. The treatments consisted of two sowing methods (broadcasting and drilling), three varieties: (LACRIWHIT-1, LACRIWHIT-4 and LACRIWHIT-5) and four fertilizer (zero fertilizer, recommended rate of NPK (120kg N, 60 kg P_2O_5 and 60 kg K_2O ha^{-1}), Farmyard Manure (FYM) at 10 t ha^{-1} and combination of half dose each of NPK (60kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}) and FYM (5 t ha^{-1})). The treatments were laid out in a Randomized Complete Block Design and replicated three times. Wheat yield was higher in 2015/2016 than in 2014/2015 dry seasons in both locations while general performance of wheat varieties at Kadawa was better than Samaru.

The result revealed that at both locations growth attributes such as plant height, number of tillers, number of leaves and dry matter varied significantly among the varieties at different sampling periods and were generally found to be higher in LACRIWHIT-5 than LACRIWHIT-1 and 4. The varieties LACRIWHIT-4 and 5 recorded more stand count than LACRIWHIT-1. The variety LACRIWHIT-5 had higher leaf area index and shorter plant especially at early growth than LACRIWHIT-1 and 4. Also, LACRIWHIT-5 had higher tiller m^{-2} and total biomass at harvest than the other varieties. The recorded number of leaves, leaf area and leaf area index varied among varieties. Also, CGR, RGR and NAR differed thought inconsistently, LACRIWHIT-5 recorded higher CGR values at various sampling stages. LACRIWHIT-1 and 4 took fewer days to heading, flowering and maturity than LACRIWHIT-5. However, LACRIWHIT-5 was found to yield higher.

Yield components such as spike m^{-2}, spike length, weight of grain $spike^{-1}$, 1000 grain weight, and biomass were higher in LACRIWHIT-5 compared to LACRIWHIT-1 and 4 at both locations. Other yield components such as number of grain $spike^{-1}$ which was low in LACRIWHIT-5 might have been compensated by 1000 and individual grain weight.

Growth parameters such as stand count, number of tillers, number of leaves, leaf area, dry matter, CGR, RGR, NAR and days to maturity were affected by sowing method and mostly favouring drill sowing than broadcast. At Kadawa in 2015/2016, broadcasted wheat produced taller plants than drilled. However, significant difference was not observed with regards to sowing methods at Samaru. The difference in grain yield due to sowing method was significant, with drill having higher yield than broadcast. Grain yield is the result of all considered yield components such as effective tillers per unit area, number of spike m^{-2}, number of grains per spike, and grain weight. These were significantly affected and the drilled wheat was favoured over broadcast. However, yield components such as number of grains per spike and 1000-grains weight were not significantly affected by sowing method.

Growth parameters such as plant height, number of tillers, number of leaves and dry matter, crop growth rate, days to 50% heading, flowering and maturity varied significantly with application of NPK or FYM alone or their combination enhancing growth of wheat.

High stand count, taller plants and more tillers were obtained under application of NPK alone or in combination with FYM than control treatment. Fertilizer application increased tiller production which directly influence leaf number and LAI of the crop.

This results in higher dry matter production for enhanced crop growth rate. Days to 50 % heading, flowering and maturity was relatively earlier in the fertilized plots compared to the unfertilized ones.

Yield components such as spike length, spike m^{-2}, 1000-grain weight, grain per spike and biomass were influenced by fertilizer application. From the study, highest yield was obtained with the application of NPK alone or in combination with FYM followed by application of FYM alone and the least was in the unfertilized control. Longer spike, more spike m^{-2}, higher 1000-grain weight, more grain per spike and biomass yield was achieved by application of fertilizer in the same manner.

Variety and sowing method interaction on stand count, leaf area index, crop dry matter, net assimilation rate, effective tillers and grain yield revealed that wheat varieties respond differently to sowing method favouring drill sowing in all the varieties for most parameters. At samaru, the varieties LACRIWHIT-4 and LACRIWHIT-5 recorded highest stand count when drill sowing was employed while at Kadawa similar and higher stand were observed. Drill sown LACRIWHIT-5 recorded high LAI followed by drilled LACRIWHIT-4 and LACRIWHIT-1. Similarly, high spike m^{-2} and grain yield were obtained in drilled sown LACRIWHIT-5.

Significant interaction between varietyand sowing method was observed in plant height, number of leaves, leaf area, leaf area index, crop dry matter, CGR, RGR, NAR, days to 50% heading, days to 50% flowering, days to maturity, effective grain filling period, biomass, harvest index and grain yield with the application of NPK alone or combined with FYM generally improving growth and yield and yield components in all the varieties. Taller plants were produced when LACRIWHIT-4 or LACRIWHIT-1 varieties were fertilized with NPK alone or combined with FYM than LACRIWHIT-5 but better response was observed in LACRIWHIT-1.

Number of leaves, leaf area, leaf area index were better developed with application of NPK alone or combined with FYM to LACRIWHIT-5 and LACRIWHIT-1 followed by LACRIWHIT-4 therefore, high dry matter production under such combination. Similarly significant interaction was observed on CGR and RGR at 6-9 WAS. Application of NPK alone or combined with FYM produced higher CGR and RGR than in the FYM alone and control plots. At both Samaru and Kadawa, heading, flowering and maturity were faster when NPK alone or combined with FYM were applied to LACRIWHIT-1 and LACRIWHIT-4. Variety x fertilizer showed delay in heading, flowering and maturity with unfertilized LACRIWHIT-5, recording the longest number of days.

Highest grain yield at Samaru was realized with LACRIWHIT-5 with application of NPK alone or combined with FYM followed by LACRIWHIT-4 and LACRIWHIT-1 with the same fertilizer. On the other hand, at Kadawa, LACRIWHIT-5 and LACRIWHIT-4 produced highest grain yield when NPK alone was applied while unfertilized plots produced least grain yield in all the varieties. Interaction of sowing method and fertilizer on stand count, plant height, leaf area, crop dry matter, CGR, RGR, NAR, days to 50% heading, days to 50% flowering, days to maturity, effective grain filling period and spike m^{-2} were significant with most of the parameters having highest response in drill sowing fertilized with NPK alone.

Positive significant correlation was observed between grain yield and most growth and yield components of wheat. These include stand count m^{-2}, plant height, number of tillers m^{-2}, LAI, crop dry matter, CGR, spike m^{-2}, spike length, spikelets spike^{-1}, number of grains spike^{-1}, weight of grains spike^{-1}, 1000 grain weight, total biomass and harvest index. Also, LAI significantly and positively correlated to CGR and CGR. The relationships between grain yield and days to 50% flowering, heading and maturity was negative. Similarly, correlation between number of grains spike^{-1} and 1000 grain weight was negative. The positive correlation between grain yield and its components showed that spike m^{-2}, number of grain spike^{-1}, weight of grains spike^{-1} and 1000 grain weight are interrelated.

In the path coefficient analysis, total biomass production had both the greatest direct and total contribution to grain yield followed by harvest index. The highest positive indirect effect was from crop dry matter via weight of grain spike^{-1} as well as number of tillers m^{-2} via total biomass at Samaru and from weight of grain spike^{-1} via total biomass at Kadawa. The low residual values obtained in study suggest that the major characters contributing to the grain yield of wheat were measured. It was realized that only 1.2%, 38.70% and 34.37% at Samaru and 11.54%, 6.0% and 7.35% at Kadawa of the variability remain unaccounted in 2014/2015, 2015/2016 and their combined mean respectively.

The economic analysis of this study revealed that, regardless of variety used, application of NPK alone gave the highest yield and this was followed by combined NPK and FYM to drilled wheat. In the combined analysis at both locations application of combined NPK and FYM to drilled LACRIWHIT-5 gave highest gross margin and profit per naira (₦) invested. The lowest gross margin resulted from broadcast sown unfertilized LACRIWHIT-1 followed by LACRIWHIT-5 under same treatment. Therefore, the yield obtained under no fertilizer and broadcast sowing might not be abundant enough to upset the cost incurred for irrigation and other management practices in wheat production.

Based on the findings of this study, it could be concluded that LACRIWHIT-5 was superior to LACRIWHIT-4 and LACRIWHIT-1 in most growth, yield attributes and yield while LACRIWHIT-1 produced more grain protein and gluten content than

LACRIWHIT-4 and 5. Drill sowing was better than broadcast in terms of most growth, yield attributes and yield. Combined application NPK (60kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}) and FYM (5 t ha^{-1}) or full rate of NPK (NPK at 120kg N, 60 kg P_2O_5 and 60 kg K_2O ha^{-1},) produced the highest grain yield. Therefore, drill sowing of variety LACRIWHIT-5 with application of either combined application of half dose of NPK and FYM or full rate of NPK (NPK at 120kg N, 60 kg P_2O_5 and 60 kg K_2O ha^{-1},), however, the application of combination of NPK and FYM in drill sown LACRIWHIT-5 was found to be economical in grain yield hence is suggested for wheat production in the Nigerian Savanna.

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APPENDICES

Appendix I: Mean maximum and minimum temperature (^0C), Relative humidity (%), sunshine hours and Pan Evaporation (mm/day) at 10 day interval during 2014/2015 and 2015/2016 dry season at Samaru

MONTH	2014/2015 RELATIVE HUMIDITY %	2014/2015 AIR TEMPERATURE (^0C) Max	2014/2015 AIR TEMPERATURE (^0C) Min	2014/2015 SUNSHINE HOURS	2014/2015 OPEN PAN EVAPORATION (mm/day)	2015/2016 RELATIVE HUMIDITY %	2015/2016 AIR TEMPERATURE (^0C) Max	2015/2016 AIR TEMPERATURE (^0C) Min	2015/2016 SUNSHINE HOURS	2015/2016 OPEN PAN EVAPOR ATION (mm/ day)
December										
1-10	2.0	35.0	15.0	NA	6.9	28.3	34.5	13.6	9.0	7.5
11-20	13.0	32.0	16.0	NA	9.4	16.5	31.3	13.9	9.4	9.7
21-31	24.0	30.0	12.0	NA	8.2	18.3	30.6	16.1	8.3	10.7
January										
1-10	36.0	23.0	14.0	NA	8.6	17.3	30.5	16.2	7.5	
11-20	36.0	35.0	15.0	NA	10.2	16.8	31.8	15.3	8.8	7.8
21-31	8.0	32.0	16.0	NA	6.8	18.6	27.4	14.6	7.5	8.6
February										
1-10	12.0	38.0	18.0	NA	12.3	16.6	31.2	16.0	7.9	8.2
11-20	17.0	35.0	21.0	NA	9.3	12.6	35.8	17.5	7.7	7.8
21-29	13.0	33.0	19.0	NA	13.6	11.4	36.7	20.8	6.7	8.3
March										
1-10	17.0	40.0	22.0	7.7	10.0	20.5	32.3	23.2	7.5	8.7
11-20	25.0	41.0	24.0	5.0	7.2	45.9	33.9	24.5	6.1	7.5
21-31	28.0	31.6	24.0	6.6	13.3	33.6	37.6	24.5	5.9	7.6
April										
1-10	32.3	37.1	22.4	6.5	9.5	45.1	38.3	25.8	7.2	15.3
11-20	9.6	32.9	21.3	6.8	13.6	57.6	39.7	26.3	7.7	7.1
21-31	19.8	38.8	20.9	8.8	11.1	50.0	40.4	25.3	8.6	8.3

Source: I A R Samaru, Agrometeorological station, A. B. U, Zaria, NA=Not available

Appendix II: Mean maximum and minimum temperature (^{0}C), Relative humidity (%), sunshine hours and Pan Evaporation (mm/day) at 10 day interval during 2014/2015 and 2015/2016 dry season at Kadawa

	2014/2015					2015/2016				
	RELATIVE HUMIDITY	AIR TEMPERATURE (^{0}C)		SUNSHINE HOURS	OPEN PAN EVAPORATION	RELATIVE HUMIDITY	AIR TEMPERATURE (^{0}C)		SUNSHINE HOURS	OPEN PAN EVAPOR ATION
MONTH	%	Max	Min		(mm/day)	%	Max	Min		(mm/ day)
December										
1-10	15.0	31.9	16.0	NA	2.9	28.2	32.0	15.1	10.3	10.3
11-20	12.0	30.2	14.8	NA	9.1	26.4	31.5	14.8	10.4	10.4
21-31	15.0	28.0	14.6	NA	9.0	31.0	29.6	13.5	9.3	9.3
January										
1-10	5.0	21.8	9.0	10.7	6.7	34.7	29.1	14.4	8.1	8.1
11-20	19.0	33.4	19.0	10.32	5.0	20.1	30.1	15.0	9.9	9.9
21-31	12.0	33.8	18.0	10.49	7.0	22.8	26.3	14.5	5.5	5.5
February										
1-10	7.0	34.9	16.0	9.18	8.0	22.9	29.8	15.3	7.9	7.9
11-20	11.0	34.6	18.2	10.45	22.0	21.1	33.9	16.7	9.8	9.8
21-29	15.0	31.6	15.6	10.47	9.3	32.1	35.0	18.3	7.5	7.5
March										
1-10	12.0	37.6	18.8	9.63	8.0	37.3	39.7	23.8	8.7	8.7
11-20	23.0	36.4	19.6	5.59	9.1	47.0	38.3	25.5	6.8	6.8
21-31	12.0	28.0	19.6	5.98	9.1	45.0	39.4	25.4	6.7	6.7
April										
1-10	18.4	40.3	25	7.42	7.5	35.3	39.7	23.7	8.7	8.7
11-20	45.5	42.4	26.3	9.54	6.5	47.0	38.3	24.9	6.8	6.8
21-31	52.5	39.3	27	6.62	7.8	43.2	37.5	26.4	7.1	7.1

Source: I A R Samaru, Agrometeorological station, A. B. U, Zaria,   NA=Not available

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