STUDIES ON WEED COMPETITION AND PERFORMANCE OF VARIOUS HERBICIDES UNDER DIFFERENT SOWING DATES AND NITROGEN LEVELS IN RAINFED COTTON (*Gossypium hirsutum* L.)

BY

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A thesis submitted to the Faculty of Agriculture of Ahmadu Bello University in partial fulfillment of the requirements for the degree of Master of Science in Agronomy

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MAY, 1983

DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented before in any previous application for a higher degree or reputable presentation elsewhere.

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Date: May, 1983.

CERTIFICATION

This thesis entitled STUDIES ON WEED COMPETITION AND PERFORMANCE OF VARIOUS HERBICIDES UNDER DIFFERENT SOWING DATES AND NITROGEN LEVELS IN RAINFED COTTON (Gossypium hirsutum L.) by Salihu A. DADARI meets the regulations governing the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to scientific knowledge and literary presentation.

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ABSTRACT

Two field experiments were carried out at the University Farm, Samaru, Zaria, in the northern guinea savanna zone during 1981 wet season. Experiment I referred as "weed competition study" consisted of two main plot treatments of sowing time (June-sowing and July-sowing) and 12 sub-plot treatments of duration of weed competition, among which six consisted of weed-free period of two weeks interval up to harvest and six of weed-infested period of two weeks interval up to harvest. Nitrogen at the rate of 30 kg N ha was applied by side dressing to the cotton crop at three weeks after sowing. Experiment II named as "weed control study", consisted of two treatments of June and July-sown cotton superimposed with three treatments of 0, 30 and 60 kg N ha and thereby constituting six main-plot treatments; and six sub-plot treatments of weed control v/here four treatments of herbicide mixtures of fluridone plus diuron @ 0.4+0.4 and 0.8+0.8 kg a.i. and norflurazon plus diuron @ 0.4+ 0.4 and 0.8 + 0.8 kg a.i. ha^{-1} were compared with hoe-weeding and unweeded check. All herbi-cide treatments were applied pre-emergence, one day after sowing.

Cotton sown on 29 June and 21 July, 1981 (referred as June-sown and July-sown crop). Spray application of "Cymbush" to the cotton crop at the rate of 2.5 1 ha to control insect-pests, was made from 10 weeks to 16 weeks after sowing. Manual picking of the seed-cotton started at 22 weeks after sowing, and continued for five weeks.

June-sown cotton outyielded that sown in July by 48 per cent in weed competition study. The most critical period of weed competition was four to six weeks after sowing in June-sown and two to six weeks in July-sown cotton. Weed dry matter production had a negative correlation co-efficient with growth, yield and yield components of cotton. In weed control studies seed cotton yield was not significantly affected by time of sowing. Cotton crop responded well to 60 kg N ha^{-1} in June-sown crop and to 30 kg N ha to July-sown crop. The most promising herbicide treatment was fluridone plus diuron at 0.8 + 0.8 kg a.i. ha^{-1} . At 60 kg N ha^{-1} an increased susceptibility of weeds to fluridone plus diuron at 0.8+ i.8 kg a.i. ha^{-1} was observed as judged by a drastic reduction in weed dry matter. Fluridone plus diuron at high rate (0.8 + t.8 kg $a.i, ha^{-1}$) in June-sown cotton under 30 and 60 kg N ha was the best herbicide ond'was- similarly effective under 60 kg N ha in July-sown crop.

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CHAPTHER I

INTRODUCTION

Cotton belongs to the family Malvaceae and two species, namely, Gossypium hirsutum (L.) and G. barbadense (L.) are grown in Nigeria. Cotton is an important source of fibre, oil and protein. The cotton frames are source of local fuel and the vegetable oil extracted from the seeds whose cake is used as a concentrated feed for livestock; however, the seed may also be fed to cattle directly. The fuzz and lint, are used for making cloth, thread, rope, felt and surgical absorbent. The domestic demand for cotton exceeds the total production. While the estimate consumption for 1981-82 season, was put to 938,090 tonnes, the actual production for that period was only 260,000 tonnes giving a net deficit of 678,090 tonnes (Gusau, 1981). Until recently, Nigeria was an important exporter of seed cotton. Production has progressively declined from 185,000 tonnes in 1971 to 90,000 tonnes in 1980. The area under cotton production has also decreased from 0.6 million to 0.3 million hectares (Gusau, 1981). Cotton yield per unit area in 1980 was 1270 kg ha^{-1} in the world, 888 kg ha^{-1} in Africa and 189 kg ha^{-1} in Nigeria (Anon., 1980). A number of factors are responsible for the low cotton yield in Nigeria. These include late planting, inadequate fertilizer application, and problem of insects diseases and weeds.

Uncontrolled weed growth in cotton field caused between 71 and 99 per cent reduction in seed cotton yield (Choudhary, 1980; Lagoke and Choudhary, 1982). Cotton fields are

commonly infested in the Nigerian savanna with a wide range of weeds, that include broadleaves including climbers, grasses and sedges. Cotton probably suffers high yield reduction due to weed competition because of the initial slow growth during the first seven weeks after planting (Kumar, et al., 1980a). Effective weed control is also important later in the season in order to provide adequate moisture and nutrients for flowering and boll formation (Anon., 1981). In Nigeria, labour scarcity and its rising cost have improved the scope for herbicide use. Various herbicides have been successfully used for weed control in cotton in Africa. However, the suitability of each chemical depends on weeds species, length of the growing season, climatic factors and management practices.

Planting time is the major factor affecting productivity of cotton. Cotton sown in mid-June fits exactly into the rainfall pattern of the northern cotton growing zone. June-sown cotton however, has a potential for high weed infestation while on the other hand, even a low level of weeds in July-sown cotton may compete seriously with the crop for moisture and nutrients which may be one limiting with the cessation of rain later in the season. There is therefore a need to study the weed-crop competition in June-sown and July-sown cotton. Judicious application of fertilizers may boost cotton production several folds, provided the crop is planted in time and protected from insects, diseases and weeds. Early-sown cotton has universally responded to nitrogen, since there is enough time during the growing

season to utilize the applied nitrogen for both vegetative and reproductive growth. Response of late-sown cotton to nitrogen is however, marginal and weed infestation may also be less, compared with the early sown cotton. Several studies have revealed that nitrogen application reduced phytotoxic effect of diuron on cotton as well as increased the susceptibility of weeds to herbicides (Buchanan and McLaughlin, 1975). The studies on weed-crop association and the performance of herbicide in irrigated cotton have been carried out in various countries. But such investigations are still to be confirmed in the rainfed cotton of the Nigerian savanna.

The objectives of this study were (1) to determine the critical period of weed competition and its effect on the performance of June-sown and July-sown cotton; (2) to evaluate the effect of sowing dates, nitrogen levels and weed control on the growth, yield and yield components of cotton.

CHAPTER II

REVIEW OF LITERATURE

A. Nature and magnitude of weed competition in cotton

Cotton grows very slowly during the first seven weeks after sowing (w.a.s) (Kumar, et al., 1982a and 1982b). There is therefore a need for a weed-free seed bed during these early period of growth. Presence of weeds during flowering and boll formation stages of cotton, compete with the crop for moisture, light and nutrients. After boll formation and during crop maturity weeds strongly compete with cotton for moisture which is usually limiting because of the cessation of rains (Faulkner and Smithson, 1972; Kumar, et al., 1982b). Weeds can also impede the impact of insecticidal sprays by sheding the cotton plants. Weeds in cotton can shed seeds and dry leaves on open cotton bolls and thus reducing the quality of the cotton produce (Klingman and Ashton, 1975). Dry season fire is a common practice among the villagers, therefore a very weedy cotton field can be proned to fire, thus resulting in yield losses.

Seed cotton yield losses ranging from 50 - 90 per cent due to heavy weed infestations have been reported in Nigeria (Anon., 1981). A decrease of 1 kg dry weed weight through weed removal increase seed cotton by 0.7 kg in the studies conducted by Kumar, et al., (1982b) at Samaru, Nigeria. Ivy and Baker (1972) and Buchanan and

Crowley (1977) reported that the competition of prickly sida with cotton can cause a reduction of cotton yield of up to 41 per cent, while Prentice, (1972) and Horowitz (1973) also indicated a reduction in seed cotton yield of 74 per cent due to weed competition. Buchanan and Burns (1970) recorded a considerable decrease in cotton height when the crop was infested with pigweed (Amaranthus retroflexus), cocklebur (Xanthium pensylvanicum) and tall morning glory (Ipomea purpurea). They further, found that the presence of weeds in cotton resulted in yield reduction due to a decrease in boll number, boll and seed weights; however, stand of cotton was not affected by weed competition.

B. Effect of period of weed competition in cotton

Crowther (1943) reported that delaying the first weeding in cotton till eight weeks after sowing, resulted in 30 per cent loss in seed cotton yield. In the Sudan, delaying the first weeding until six weeks reduced the yield of seed cotton by 75 per cent and additional weeding later had little effect since it only increased yield by 20 per cent (Kerkhoven, 1964). The same author while working in the poorly drained soil of Kafue flat in Zambia found an increase of 74 per cent in cotton yield from the crop weeded at six weeks. Delay in the removal of weeds till two weeks after sowing and more produced a linear decrease in plant height, boll number and seed cotton yield (Singh and Singh, 1971). Beltrao, et al. (1974) working at Paraiba and Per Nambuco state in South

America, found that yield losses in cotton due to weed competition was greatest during the first eight weeks or more and the plant height, boll number and leaf number were all reduced.

Annual weed infestation during the first six weeks resulted in about 36 per cent reduction in potential seed cotton yield at Samaru, Nigeria, while about 42 per cent reduction in yield was obtained at Buruku, Nigeria, where Rottboelia exaltata was the dominant weed (Anon., 1982). The high demand for both moisture and nutrients at eight weeks after sowing by cotton crop has necessitated weed removal at flowering stage (Lawes, 1968). Kumar, et al. (1982b) working on crop-weed competition at Samaru, Nigeria, emphasized the importance of weeding during peak flowering period in early sown cotton and effective weed control resulted in an increase of 165 per cent seed cotton yield over early three weedings. Faulkner and Smithson (1972) while working at Samaru, reported that after boll formation and during crop maturity the presence of weeds strongly compete with crop for moisture which becomes limiting due to cessation of rains. Some studies have focused on the period of weed competition and the optimum timing of weed control. Marthinez and Nieto (1968) reported that maximum spring cotton yield in Mexico required a weed-free period of 60 days after emergence and that no yield loss occured if weeds were removed within 30 days of emergence. Thomas and Schwerzel (1968) found that weeds emerging

after hand cultivation at four to eight weeks of crop emergence did not reduce seed cotton yield. Drennah and Jenings (1977) while working in the Sudan Gezira reported that the critical period of weed competition in cotton occured between four and ten weeks after crop emergence. In Colombia, South Africa, the critical period of weed competition in cotton is between three and six weeks after sowing (Chaves, 1970). According to Rogers et al. (1976), cotton has two to four weeks weed-free requirement where Amaranthus retroflexus was the dominant weed. Buchanan and McLaughlin (1975) observed that cotton tolerated only six weeks of competition at zero N rate whereas it tolerated seven weeks of competition at 67 and 100kg N ha^{-1} (Beltrao, et al., 1979).

Weed species in cotton

Of the numerous weeds that infest cotton in the Nigerian savanna, the following are of major importance: Cyperus esculentus (L.), C. rotundus (L.), Cynodon dactylon (L.), Cleome ciliata (Schum and Thounn), Digitaria sanguinalis (Rotz.), Eleusine indica (L.) Eragrostis tenella (L.), Mucuna pruriens (L.), Rottboelia exaltata (L.), Solanum villosum (L), Sorghum halepense (L), and Vernonia cinerea (L.) (Choudhary, 1980; Lagoke and Choudhary, 1982). In a "cotton maximum yield plot" under ten year of cultivation at Samaru, Zaria, the common weeds observed during the flowering stage were Ageratum conyzoides (L.), Cyperus exculentus, C. rotundus, Digitaria ciliaris and Eragrostis tenella (L.). Broad [illegible]d

weeds constituted 85 per cent of total weed weight and population (Kumar, 1982). Elsewhere in the tropical and sub-tropical cotton growing regions of the world, the following weeds are considered important, Amaranthus retroflexus (L.), Brachiaria eruciformis (Schum.), Chenopodium album (L.), Cynodon dactylon, Echinochloa colonum (L.), Leptochloa filiformis (L.), Panicum fasciculatum (Jacq.), Phalaris paradoxa (L.), Physalis wrightii (L.) Portulaca oleracea (L.) Setaria verticillata (L.), Tribulus terrestris (L.), Tripleurospermum maritimum (L.), Phyncosia memnonia (L.) and Thlaspi arvensis (Schum.), (Arle and Hamilton, 1966; Bakumenko, et al., 1967; Idris, 1970 and Luz, et al., 1968).

D. Chemical weed control in cotton

Various herbicides have been selectively used for weed control in cotton in different parts of the world. Among those reported by various researchers - fluridone, fluometuron and diuron have so far been tested in different ecological zones of cotton production in Nigeria (Ogborn, 1976; Amon., 1978; Choudhary, 1980; Lagoke and Choudhary, 1982).

1. Pre-plant herbicides

In a trial on irrigated cotton, crop emergence, seedling growth and yield of the crop was unaffected by pre-plant application of bensulide which was also very effective on annual weeds like Amaranthus viridis, Echinochloa colonum, Leptochloa filiformis, Panicum

fasciculatum and Physalis wrightii (Arle and Hamilton, 1966). In Sao Paulo, South America, trifluralin applied pre-plant and incorporated, gave excellent control of grasses but not of broad-leaved weeds (Alves, 1967). Trifluralin and nitralin which are more effective on grasses than broad-leaf weeds have been recommended as soil incorporated pre-plant treatments (Richards and van Linclert, 1968 and Danielson, 1969). Diuron at 1 or 2 kg a.i. ha^{-1} was observed suitable as a pre-sowing herbicide for cotton, 1 kg a.i. ha^{-1} was effective on weeds for seven weeks while 1.5 to 2 kg a.i. ha^{-1} controlled weeds throughout the growing season (Rijn, 1967). In the drier parts of USA about 1 to 2 kg a.i. ha^{-1} of diuron and prometryne were recommended just before the pre-planting irrigation and before the seed-beds are prepared (Anon., 1969). There are however, reports that the pre-plant use of diuron may increase the susceptibility of cotton to Rhizoctonia solani (Hamilton et al., 1966). Fluridone at the rate of 1.8 kg a.i. ha^{-1} incorporated before sowing cotton, showed excellent selectivity and controlled a broad spectrum of grasses and broad-leaf weeds (Banks and Merkle, 1978, 1979; Buendia et al., 1978). Ogborn (1969) working in northern Nigeria, reported that trifluralin applied a month before sowing cotton reduced the weeds removed during site preparation by two thirds and annual grasses are well controlled by the herbicide.

2. Pre-emergence herbicides

Korolev (1974) reported that pre-emergence application of fluometuron at the rate of 3 kg a.i. ha^{-1} gave 99 per cent control of annual weeds up to 60 days after sowing. Pre-emergence treatments recommended in the USA and elsewhere were chlorpropham 4.5 to 11 kg a.i. ha^{-1}, chlorothal dimethyl 4.5 to 9 kg a.i. ha^{-1}, diuron 0.4 to 1.75 kg a.i. ha^{-1}, fluometuron 1.2 kg a.i. ha^{-1}, monuron 1.75 kg a.i. ha^{-1}, noruron 0.8 to 2.75 kg a.i. ha^{-1}, prometryne 1.75 to 2.5 kg a.i. ha^{-1} (Anon., 1968, 1969; Danielson, 1969). Fluridone at the rate of 0.2 kg a.i. ha^{-1} has reportedly given excellent selective control of many annual weeds while effective control of perennial weeds was obtained with slightly higher rates of 0.5 kg a.i. ha^{-1} (Buendia et al., 1978; Banks and Merkle, 1978 and 1979; Thomas, 1974). Fluridone at 0.3 kg a.i. ha^{-1} controlled Amaranthus hybridus (L.), Datura stramonium (L.), while 0.6 kg a.i. ha^{-1} controlled Abutilon guinense (Schum.), Malva verticillata (L.) and the control of Cyperus rotundus was also good without any phytotoxicity to the crop. Pre-emergence application of diuron at the rate of 0.85 kg a.i. ha^{-1}, gave 78 per cent control of weeds in cotton and resulted in the highest net return (Ahlawat, 1978). Baker (1978) reported that norflurazon at the rate of 1 to 2 kg a.i. ha^{-1} controlled annual grasses satisfactorily when applied as a pre-emergence treatment to cotton fields. Pre-emergence application of fluridone at 0.4 and 0.8

kg a.i. ha^{-1}, reduced weed weights significantly in cotton for 8 weeks after sowing (Lagoke and Choudhary, 1982).

3. Post-emergence herbicides

Paraquat was observed to be a promising herbicide for general weed control in cotton as a post-emergence directed spray (Arle and Hamilton, 1966). For general weed control the substituted ureas and triazines are recommended as directed sprays from the time cotton is about 15 cm tall. The normal rate of 0.4 kg a.i. ha^{-1} diuron or 1 kg a.i. ha^{-1} fluometuron can be halved by the addition of a non-phytotoxic oil to the spray liquid at about 5 - 10 per cent on volume per volume basis (Hardcastle and Wilkinson, 1968). Formerly naphtha oils were repeatedly and widely used in cotton; they were applied as directed spray at a rate of 200 litres per hectare after the cotton seedlings have attained the height of 5 to 7.5 cm. Application was avoided when the stems cracked and care was taken to avoid contact with the cotton leaves (Palmer and Ennis, 1960; Danielson, 1969). Singh and Singh (1971) stressed that control of weeds 15 days after crop emergence produced optimum growth and highest seed cotton yield Application of glyphosate in cotton by using the rope wick on weeds, appears to have good promise as selective weed control (Anon., 1975).

4. Herbicide combinations

Akobundu et al. (1975) reported that weeds can be controlled by reduced rates of herbicides when used in

the proper combination that gave synergistic effects. Hegab (1974) reported that trifluralin at 1.13 kg a.i. ha^{-1} plus fluometuron at 2.25 kg a.i. ha^{-1}, controlled weeds effectively in cotton when applied as either pre-plant or pre-emergence. Le-Rumeus (1974) observed that trifluralin, dinitramine at 1.2 kg a.i. ha^{-1} and fluometuron at 2 kg a.i. ha^{-1} pre-emergence gave the best control of weeds in cotton crop. Arle and Hamilton (1977) reported effective weed control in cotton when diuron mixed with trifluralin were applied to cotton at pre-emergence. Butralin at 2.25 kg a.i. ha^{-1} plus diuron gave excellent control of Sorghum halepense (L.) when applied as pre-emergence (Hurst and Smith, 1978).

De-Almeida (1969) had the best weed control with sequential application of trifluralin at 0.9 kg a.i. ha^{-1}, incorporated before sowing followed by fluometuron at 2.25 kg a.i. ha^{-1} as pre-emergence. Baker and Tupper (1972) reported that trifluralin at 6.25 kg a.i. ha^{-1} pre-emergence proved most effective in controlling weeds in cotton crop. Borhorquez and Salazar (1975) were of the opinion that most of the herbicides used in weed control in cotton are only effective on weeds about 40 - 45 days; therefore, with pre-emergence application of fluometuron at 2 kg a.i. ha^{-1} plus alachlor at 1.5 kg a.i. ha^{-1} a hoe-weeding at 55 days after sowing was necessary. With a weed flora dominated by Cyperus rotundus, a pre-emergence application of norflurazon at 1 kg a.i. ha^{-1}, followed by MSMA at 2 kg a.i. ha^{-1} at

post-emergence gave long season weed control and good seed cotton yield (Anon., 1976). It was reported by Karnail (1976) that application of herbicides alone was not as good as three hoeings in respect of seed cotton yield, but upland cotton responded well to the use of herbicides combined with one hoe-weeding. Toro and Sion (1976) stated that the best yield of seed cotton was obtained when alachlor at 1.15 kg a.i. ha^{-1} plus diuron at 1 kg a.i. ha^{-1} were applied pre-emergence and followed by hoe-weeding 45 days later. Hamdoun and Babiker (1978) observed that pre-emergence application of oxadiazon plus diuron or norflurazon gave satisfactory weed control, particularly during early stages of cotton growth and supplementary hand weeding six weeks after sowing was necessary for the control of resistant weed species. On plots infested with Ipomea purpurea (L.) and Amaranthus retroflexus (L.), soil-incorporation of nitralin at 0.5 and 1.0 kg a.i. ha^{-1} prior to bedding followed by prometryne, fluometuron, monuron or diuron applied at recommended rate immediately after sowing or few weeks later gave better weed control than any of the treatments applied singly (Yepes, 1978). It was observed by Lagoke and Choudhary (1982) that on a heavy black cotton soil, fluridone and its mixtures with diuron followed by supplementary hoe-weeding were the only herbicide treatments that resulted in yields comparable to hoe-weeded check.

E. Effect of sowing dates on cotton

Koli (1973) reported optimum sowing dates in the north and south of Ghana as May-June and early July-August respectively and delay of one month in sowing resulted in decrease in seed cotton yields of about 42 and 52 per cent. Burham and Jackson (1973) and Husseini et al. (1978) also reported a decrease in seed cotton yield with delay in sowing dates. A yield decrease with delay in sowing dates of cotton was reported by Beltrao et al. (1979), moreover, plant height and number of days to boll formation were highest for the first sowing date. Ogunlela et al. (1981) reported that mid-June and mid-July sown cotton, yield optimum in eastern and southern cotton zone; while a recent work by Kumar at al. (1982b) favours early planting of cotton in the northern cotton zone of Nigeria. These workers have also reported severe weed competition in early-sown cotton. On the other hands weeds in July-sown cotton must be competing strongly for moisture which is a limiting factor during crop maturity period due to closer of rains (Faulkner and Smithson, 1972).

F. Effect of nitrogen on cotton

Perkins and Douglas (1965), Choudhary (1969) and Anderson (1974) reported increase in height of cotton plants by applying nitrogen fertilizer. Abdullah (1976), Hassan (1976) and Thomas et al. (1976) found that cotton leaf area per stand increased with the increase in nitrogen

fertilizer rates. Choudhary (1969), Eid (1969) and Gabr et al. (1975) observed a significant increase in the number of open bolls per plant, weight of seed cotton per boll and seed index as the level of nitrogen fertilizer increased.

Wahab (1963) indicated that differences in yields of cotton were negligible when nitrogen level was increased from 84.4 to 138.1 kg a.i. ha^{-1}, while Singh and Dargan (1965) and Singh and Singh (1971) observed that application of nitrogen brought about significant and proportionate increase in seed cotton yield. Kumar et al. (1982b) working in northern Nigeria, reported that 40 kg N ha^{-1} was optimum level for July-sown cotton, while the June-sown crop responded to 50 kg N ha^{-1} or more (Lombin and Ogunlela, 1982). Early-sown cotton, however, responded considerably better to nitrogen as compared to late-sown (July) crop (Kumar and Ogunlela, 1982). Weed reduced yields of upland cotton by 43 to 63 per cent and the response of the crop to fertilizers increased when weeds were controlled completely (Wankhede, 1970).

G. The performance of herbicides as affected by fertilizers

Liming has been found to increase the activity of prometryne, diuron and fluometuron for effective weed control in cotton (Savage and Bardley, 1966). It has been observed that the selectivity of prometryne in controlling weeds in cotton can be increased by applying

CHAPTER III

MATERIALS AND METHODS

A. Site

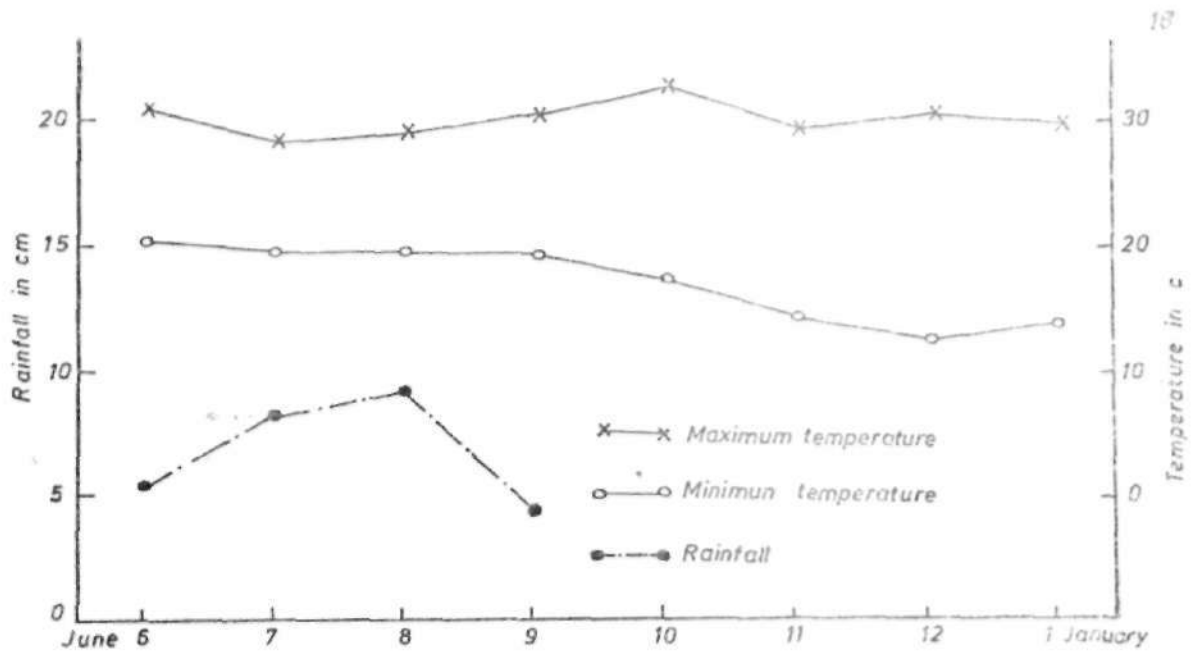
1. Location and weather

Two sets of field investigations were carried out at the University Farm, Samaru ($11^{O}11'N$; $07^{O}38'E$) in the northern guinea savanna zone during 1981 wet season. Experiment I was designed to find out the critical period of weed competition in June and July-sown cotton. Experiment II was to evaluate the effect of sowing dates, nitrogen levels and weed control treatments on the growth and yield of cotton. Henceforth, in this manuscript, Experiment I will be referred to as "weed competition study" and Experiment II as "weed control study".

The climatic conditions of the site are shown in Fig.1. The minimum air temperature ranged from 12.2 to 21.1°C while the maximum was from 25.6 to 33.3 C during the crop growing season (Table 1). Highest relative humidity of 84.3 per cent was observed in July. The total rainfall received during the crop cycle of June-sown cotton was 721.7mm and 444.0mm for the July-sown crop. Sunshine duration was relatively larger during the fourth week of October.

B. Field characteristics

The soil at the University Farm, Samaru is a sandy loam and is well drained. Details of the physical and chemical properties of the soil are summarised in Table 2.



Mean monthly minimum and maximum air temperature and rainfall at University Farm, Samaru.
(June 1981 to January 1982)

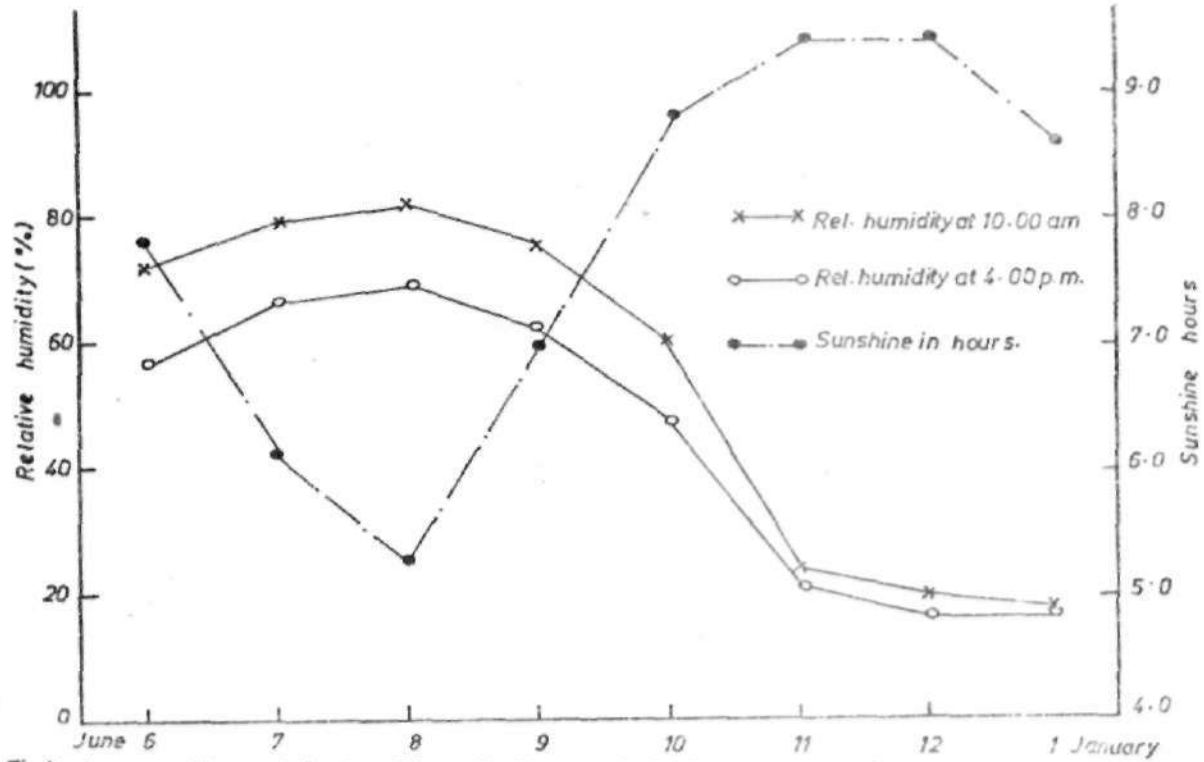


Fig.1: Mean monthly relative humidity at 10·00 am and 4.00 p.m. and sunshine hours at University Farm, Samaru (June 1981 to January 1982).

Table 1: The fortnightly minimum and maximum air temperature from June 1981 to January 1982.

Fortnights	Air Temperature (C) Maximum Mean	Minimum Mean
June 1981		
1 fortnight	33.0	21.1
2 fortnight	28.6	20.0
July		
1 fortnight	28.8	19.7
2 fortnight	29.3	20.7
August		
1 fortnight	29.5	19.8
2 fortnight	27.4	19.2
September		
1 fortnight	29.4	19.1
2 fortnight	30.7	19.7
October		
1 fortnight	31.8	18.8
2 fortnight	33.3	15.9
November		
1 fortnight	31.0	14.7
2 fortnight	25.6	12.8
December		
1 fortnight	29.5	13.2
2 fortnight	30.9	12.2
January		
1 fortnight	28.7	12.7
2 fortnight	30.7	15.2

Table 2: Physical and chemical properties of the soil at the University Farm, Samaru

Mechanical composition	(%)
Clay	10
Fine silt	43
Coarse silt	7
Fine sand	28
Medium sand	8
Coarse sand	4
Organic carbon	0.44
Total-N	0.024
Available-N	56.30ppm
pH	5.9 H_2O 1:1

C. Cultural practices

1. Field operation and fertilization

The experimental site was ploughed once and harrowed twice within a week. Fertilizers of Boronated superphosphate at the rate of 22 kg P_2O_5, 0.7 kg B and 66 kg K_2O ha^{-1} (muriate of potash) were broadcasted uniformly after the second harrowing and before ridging at 75 cm apart. Nitrogen at the rate of 30 kg ha^{-1} (CAN) was applied by side dressing to the cotton crop in the weed competition study three weeks after sowing (w.a.s). In the weed control experiment where nitrogen levels were part of the main-plot treatments, all levels of nitrogen were applied at three weeks after sowing.

2. Planting and spacing

Cotton (var. Samaru 71) seeds were sown on the June 29 and July 21, 1981, for the first and second dates of sowing, respectively. About seven seeds were sown per hill at three cm depth, at an intra-row spacing of 45 cm. Vacancies were supplied at 14 days after sowing. The entire crop was thinned to two plants per stand at three weeks after the initial sowing to give a plant population of about 31,800 stands per hectare.

3. Herbicide application

All herbicide treatments were applied pre-emergence, one day after sowing using a Knapsack Sprayer (CP3) equipped with a polijet nozzle and operated at a pressure of 2.1 kg per cm. The delivery rate of the sprayer was

5. Crop vigour

The vigour was assessed at 12 weeks after sowing using a zero to ten scale. A score of ten was given to the plot with most healthy plants and zero to the plots with dead plants (4 for height; 4 for spread and 2 for colour. The plots scaled from 2.5 to 5 were considered of healthy plants and those scaled above 5 were very healthy.

6. Plant height, flower and boll counts

Four plants were randomly selected in each plot and tagged for later assessment of plant height, flowering and boll counts at 10, 11 and 18 weeks after sowing respectively.

7. Dry weights of frame, leaves and bolls

During the first cotton picking, random samples of two stands per plot were cut, to the ground level and separated into frame, leaves and bolls. These were oven-dried at 70 C for three days to constant weight for dry matter assessment.

8. Cotton yield

Plants in the inner two rows (net plot) 7.5 m^2, were handpicked and seed cotton yield was converted in kg ha^{-1} basis. Picking was done thrice in each plot.

9. Stand count

This was done immediately after harvest from the two rows (net plot) and computed on hectare basis.

F. Statistical analysis

The data collected were subjected to statistical analysis of variance as described by Little and Hill (1972). Differences between the treatment means in Experiment I were compared using the Duncan Multiple Range Test. Analysis of variance of seed cotton yield and weed dry matter production are shown in appendix 2 and 3 respectively. In Experiment II, treatment means were compared by using the Least Significant Difference (LSD), wherever the F value was significant (P = 0.05). The analysis of variances of seed cotton yield is shown in Appendix 4 and that of weed dry matter in Appendix 5.

CHAPTER IV

RESULTS

A. Weed competition study (Experiment I)

1. Crop growth components

a. Crop vigour

June-sown cotton plants were significantly more vigorous than those sown in July (Table 3). Vigour scores of the plots kept weed-free for the first four w.a.s., were significantly lower than those kept weed-free throughout. Weed interference with cotton crop till four weeks of crop growth and more resulted in a significantly lower vigour score than that of the crop kept weed-infested for six, eight and ten w.a.s. or until harvest were also similar. The interaction between date of sowing and periods of weed-association was significant (Table 4). In June-sown cotton, the plots kept weed-free for the first four weeks, and those weed-infested for six w.a.s. and longer periods, had lower crop vigour score than those kept weed-free throughout. the growing season.

Vigour scores in the crop kept weed-free for two w.a.s., and those unweeded from eight w.a.s. and until harvest were similar. In the July-sown crop, the plants kept weed-free initially for various periods of crop growth and those weedy till two w.a.s., had similar crop vigour scores.

Table 3: Effect of sowing dates and period of weed competition on crop vigour of cotton at eight weeks after sowing.

Treatments	Crop vigour score*
Main-plot	
Sowing dates	
June	5.6 A
July	4.1 B
Sub-plot	
Duration of weed competition	
Weed-free periods	
2 weeks after sowing	4.3 cd
4 weeks after sowing	5.4 b
6 weeks after sowing	6.3 ab
8 weeks after sowing	5.9 ab
10 weeks after sowing	6.0 ab
to harvest	6.6 a
Weed-infested periods	
2 weeks after sowing	5.9 ab
4 weeks after sowing	5.3 bc
6 weeks after sowing	4.3 cde
8 weeks after sowing	3.3 de
10 weeks after sowing	3.4 de
to harvest	2.9 e
Interaction	
Sowing dates x Weed competition	Significant

Means followed by the same letter in the same treatment factor do not differ significantly at the 5% level of probability according to Duncan's multiple range test.

*2.5 - 5.0 = Healthy plant;
5 = Very healthy plant.

Table 4: The interaction effect of sowing dates and period of weed competition on the crop vigour score of cotton at eight weeks after sowing.

Treatments	Planting date	
	June	July
	Crop vigour score*	
Duration of weed competition		
Weed-free periods		
2 weeks after sowing	4.6 efg	4.0 efghi
4 weeks after sowing	5.6 bcde	5.1 cde
6 weeks after sowing	7.6 a	5.0 cde
8 weeks after sowing	7.0 ab	4.9 def
10 weeks after sowing	6.6 abc	5.4 bcde
to harvest	7.5 a	5.6 bcde
Weed-infested periods		
2 weeks after sowing	6.3 abcd	5.5 bcde
4 weeks after sowing	7.3 a	3.4 fghij
6 weeks after sowing	5.5 bcde	3.1 ghij
8 weeks after sowing	4.1 efgh	2.5 ij
10 weeks after sowing	4.1 efgh	2.8 hij
to harvest	3.4 fghij	2.4 j

Means followed by the same letter do not differ significantly at the 5% level of probability according to Duncan's multiple range test.

*2.5 - 5.0 = Healthy plant;
5 = Very healthy plant.

Unlike the June-sowing, plants weed-infested for four w.a.s. and longer were comparable in vigour to those kept weedy till harvest.

b. Plant height

Although June-sown cotton plants were taller than those planted in July, this height difference was not significant (Table 5). Cotton plants of the plots kept weed-free throughout were significantly taller than those weed-infested throughout. The crop kept weed-free for the first two weeks only, or weed-infested for eight w.a.s. and longer, resulted in shorter plants than those of the plots kept weed-free until harvest. Weed-infestation duration of six w.a.s. resulted in significantly shorter cotton plants than when weed-infestation lasted for the first two weeks only. Plants height was similar in unweeded cotton plots and plots weed-infested for 8 - 10 w.a.s. The interaction between planting date and period of weed-competition on crop height was not significant. Plant heights of June and July-sown cotton were negatively correlated with weed weight (Tables 14 and 15 respectively).

c. Leaf dry weight

Leaf dry matter production in cotton was not significantly affected by the sowing date, but by the duration of weed competition (Table 6). Uncontrolled weed growth throughout crop 1[illegible] cycle significantly reduced leaf dry weight in

Table 6: Effect of sowing dates and period of weed competition on the height of cotton, ten weeks after sowing.

Treatments	Plant height in cm
Main-plot	
Sowing dates	
June	84.8 A
July	76.5 A
Sub-plot	
Duration of weed competition	
Weed-free periods	
2 weeks after sowing	71.7 cde
4 weeks after sowing	82.7 abc
6 weeks after sowing	93.4 ab
8 weeks after sowing	97.6 ab
10 weeks after sowing	88.3 abc
to harvest	94.8 ab
Weed-infested periods	
2 weeks after sowing	99.4 a
4 weeks after sowing	86.5 abc
6 weeks after sowing	80.5 bcd
8 weeks after sowing	56.2 ef
10 weeks after sowing	64.2 def
to harvest	52.8 f
Interaction	
Sowing dates x Weed competition	Not significant

Means followed by the same letter in the same treatment factor do not differ significantly at the 5% level of probability according to Duncan's multiple range test.

Table 6: Effect of sowing dates and period of weed competition on leaf and frame dry weights of cotton, 22 weeks after sowing.

Treatments	Leaf dry weight (g) per stand	Frame dry weight (g) per stand
Main-plot		
Sowing dates		
June	7.0 A	33.0 A
July	5.0 A	31.0 A
Sub-plot		
Duration of weed competition		
Weed-free periods		
2 weeks after sowing	2.0 d	20.0 def
4 weeks after sowing	2.0 d	30.0 bcde
6 weeks after sowing	4.0 bcd	43.0 ab
8 weeks after sowing	5.0 abcd	42.0 abc
10 weeks after sowing	8.0 ab	40.0 bc
to harvest	9.0 a	61.0 a
Weed-infested periods		
2 weeksaafter sowing	9.0 a	48.0 ab
4 weeks after sowing	8.0 ab	37.0 bcd
6 weeks after sowing	9.0 a	25.0 cdef
8 weeks after sowing	9.0 a	15.0 ef
10 weeks after sowing	6.0 abc	18.0 def
to harvest	3.0 cd	9.0 f
Interaction		
Sowing dates x Weed competition	Not significant	

Means within a column for each character followed by the same letter in the same treatment factor do not differ significantly at 5% level of probability according to Duncan's multiple range test.

count (Table 7). Weed-infestation for a period of more than two w.a.s. significantly reduced flower count relative to the weed-free treatment. The same result was also obtained when the period cotton was kept weed-free does not exceed four w.a.s. High flower count require that weed competition in cotton be reduced from six w.a.s. until crop harvest.

b. Boll number

Planting date had no significant effect on boll number (Table 8). The ability of cotton to produce optimum number of bolls was not affected by weeds competition during the first six w.a.s. Similarly keeping cotton field weed-free from six w.a.s. until harvest resulted in boll numbers per plant that were as high as in field that were kept weed-free from planting to harvest. A significant reduction in boll number relative to the weed-free plot was observed when cotton was either kept weed-free for early four w.a.s. or left unweeded for periods longer than six w.a.s.

The interaction effect of sowing date and period of weed competition with the crop was not significant for boll number. There were highly positive correlations between boll number and plant height on one hand and boll number and seed cotton yield on the other (Tables 14 and 15). These yield components were negatively correlated with weed weight.

Table 7: Effect of sowing dates and period of weed competition on flower number of cotton recorded, 11 weeks after sowing.

Treatments	Number of flowers per stand
Main-plot	
Sowing dates	
June	12.4 A
July	10.5 A
Sub-plot	
Duration of weed competition	
Weed-free periods	
2 weeks after sowing	7.9 ef
4 weeks after sowing	10.5 de
6 weeks after sowing	15.6 ab
8 weeks after sowing	15.1 abc
10 weeks after sowing	14.8 bc
to harvest	17.2 ab
Weed-infested periods	
2 weeks after sowing	18.9 a
4 weeks after sowing	14.2 bcd
6 weeks after sowing	11.4 cde
8 weeks after sowing	3.5 g
10 weeks after sowing	5.5 fg
to harvest	3.1 g
Interaction	
Sowing dates x Weed comptition	Not significant

Means within a column followed by same letter in the same treatment factor do not differ significantly at 5% level of probability according to Duncan's multiple range test.

Table 8: Effect of sowing dates and period of weed competition on boll number of cotton, 13 weeks after sowing.

Treatments	Boll number per stand
Main-plot	
Sowing dates	
June	13.9 A
July	11.6 A
Sub-plot	
Duration of weed competition	
Weed-free periods	
2 weeks after sowing	7.9 cd
4 weeks after sowing	10.0 c
6 weeks after sowing	16.1 ab
8 weeks after sowing	15.3 b
10 weeks after sowing	16.8 ab
to harvest	18.7 ab
Weed-infested periods	
2 weeks after sowing	20.7 a
4 weeks after sowing	16.5 ab
6 weeks after sowing	15.9 ab
8 weeks after sowing	4.9 de
10 weeks after sowing	6.7 cde
to harvest	3.3 e
Interaction	
Sowing dates x Weed competition	Not significant

Means within a column followed by the same letter in the same treatment factors do not differ significantly at 5% level of probability according to Duncan's multiple range test.

c. Boll dry weight

Sowing date did not have a significant effect on boll dry matter production in cotton. However, weed competition with the crop adversely affected the boll dry weight (Table 9). Both keeping cotton weed-free during the first four w.a.s. and weed-infested for eight w.a.s. or more, resulted in significant reduction of boll dry weight as compared with either the crop kept weed-free from six w.a.s. to harvest or the one that was weed-infested for only the first six w.a.s.

The interaction of sowing date and period of weed competition on cotton boll dry matter production was not significant. As reported for boll number, boll dry weight was also positively correlated with plant height and with seed cotton yield (Table 14). A significant negative correlation was also obtained between boll dry weight and weed dry matter.

d. Seed cotton yield

June-sown cotton significantly outyielded the July-sown crop (Table 10) and the duration of weed competition significantly affected seed-cotton yield. Seed cotton yields of plots kept weed-free for the first four w.a.s. and those weed-infested for periods greater than six w.a.s. were similar and significantly lower than yield from those plots that were weed-infested for only six w.a.s.

Table 9: *Effect of sowing dates and period of weed competition on boll dry weight of cotton, 22 weeks after sowing.*

Treatments	Boll dry weight (g) per stand
Main-plot	
Sowing dates	
June	63.0 A
July	61.0 A
Sub-plot	
Duration of weed competition	
Weed-free periods	
2 weeks after sowing	32.0 ef
4 weeks after sowing	46.0 cdef
6 weeks after sowing	75.0 abc
8 weeks after sowing	76.0 abc
10 weeks after sowing	86.0 ab
to harvest	93.0 ab
Weed-infested periods	
2 weeks after sowing	97.0 a
4 weeks after sowing	71.0 abcd
6 weeks after sowing	62.0 bcde
8 weeks after sowing	44.0 cdef
10 weeks after sowing	42.0 def
to harvest	17.0 f
Interaction	
Sowing dates x Weed competition	Not significant

Means within a column followed by the same letter in the same treatment factor do not differ significantly at 5% level of probability according to Duncan's multiple range test.

Table 10: Effect of sowing dates and period of weed competition on seed cotton yield.

Treatments	Seed cotton yield kg ha^{-1}
Main-plot	
Sowing dates	
June	1675.1 A
July	1135.8 B
Sub-plot	
Duration of weed competition	
Weed-free periods	
2 weeks after sowing	706.7 c
4 weeks after sowing	1042.8 bc
6 weeks after sowing	1893.0 a
8 weeks after sowing	1827.9 a
10 weeks after sowing	1699.0 a
to harvest	2007.2 a
Weed-infested periods	
2 weeks after sowing	2012.5 a
4 weeks after sowing	1647.2 a
6 weeks after sowing	1461.2 ab
8 weeks after sowing	956.4 bc
10 weeks after sowing	932.5 bc
to harvest	678.8 c
Interaction	
Sowing dates x Weed competition	Significant

Means followed by the same letter in the same treatment factor do not differ significantly at the 5% level of probability according to Duncan's multiple range test.

Highest seed yields were obtained when the cotton crop was either kept weed-free for the first six weeks of growth or was weed-infested for the first four w.a.s. only. Although weed competition duration of four to six w.a.s. did not significantly depress yield, crop yield was limited to only two w.a.s. Weed-infestation throughout crop life cycle resulted in 66 per cent reduction in seed cotton yield compared with the weed-free crop.

The interaction between sowing dates and weed competition with the crop was significant (Table 11). In the June-sown cotton, significantly lower seed-cotton yield was obtained when the crop was kept weed-free for the first four w.a.s only or weed-infested for a period of six weeks and longer than the crop kept weed-free until harvest. Seed cotton yield in the July-sown cotton was generally poorer across all weed competition treatments than the June-sown cotton. Seed yield in the July-sown cotton was inferior to June-sown cotton that was not weeded for the first four w.a.s. Uncontrolled weed growth caused 74 per cent and 62 per cent yield reduction in July-sown and June-sown cotton respectively. Seed cotton yield in the June and July-sown crop had high positive correlation with plant height, frame weight, boll number and boll dry weight (Tables 14 and 15).

Table 11: The interaction effect of sowing dates and period of weed competition on seed cotton yield in kg ha^{-1}.

Treatments	Sowing dates June		July	
	Seed cotton yield kg ha^{-1}			
Duration of weed competition				
Weed-free periods				
2 weeks after sowing	624.3	ij	797.0	ghij
4 weeks after sowing	916.6	fghij	1169.0	fghij
6 weeks after sowing	2311.4	abc	1487.8	cdefg
8 weeks after sowing	2377.8	ab	1288.5	efghi
10 weeks after sowing	2019.2	abcde	1381.5	defghi
to harvest	2577.1	a	1448.0	defgh
Weed-infested periods				
2 weeks after sowing	2324.7	ab	1700.4	bcdef
4 weeks after sowing	2072.3	abcd	1222.1	efghi
6 weeks after sowing	1594.1	bcdefg	1328.4	defghi
8 weeks after sowing	1129.1	fghij	783.8	ghij
10 weeks after sowing	1248.7	efghi	664.2	hij
to harvest	983.0	fghij	372.0	j

Means followed by the same letter do not differ at the 5% level of probability according to Duncan's multiple range test.

Table 12: Effect of sowing dates and period of weed competition on the dry weight of weeds in cotton.

Treatments	Weed dry weight kg ha^{-1}
Main-plot	
Sowing dates	
June	2614.0 A
July	1751.2 A
Sub-plot	
Duration of weed competition	
Weed-free periods	
2 weeks after sowing	1677.6 cd
4 weeks after sowing	1337.2 d
6 weeks after sowing	1131.2 d
8 weeks after sowing	885.6 d
10 weeks after sowing	820.4 d
to harvest	723.6 d
Weed-infested periods	
2 weeks after sowing	1301.6 d
4 weeks after sowing	1991.2 cd
6 weeks after sowing	2006.0 bcd
8 weeks after sowing	3406.0 bc
10 weeks after sowing	3781.0 b
to harvest	7129.6 a
Interaction	
Sowing dates x Weed comptition	Significant

Means within the column followed by the same letter in the same treatments factor do not differ significantly at the 5% level of probability according to Duncan's multiple range test.

Table 13: The interaction effect of sowing dates and weed competition on the dry weight of weeds in cotton

Treatments	Sowing dates	
	June	July
	Weed dry weight kg ha^{-1}	
Duration of weed competition		
d-free periods		
2 weeks after sowing	2502.0 bed	853.2 d
4 weeks after cowing	1971.2 cd	703,2 d
6 weeks after sowing	1276.4 d	986.0 d
8 weeks after sowing	984.0 d	787.2 d
10 weeks after sowing	862.0 d	779.2 d
to harvest	665.2 d	782.0 d
d-infested periods		
2 weeks after sowing	1328.0 d	1275-2 d
4 weeks after sowing	1301.6 d	2681.2 bed
6 weeks after sowing	1561.2 d	2450.4 abc
8 weeks after sowing	4446.0 be	2366.0 abc
10 weeks after sowing	4867.2 b	2696.0 bed
to harvest	9605.2 a	4654.4 b

Means followed by the same letter do not differ at the 5% level of probability according to Duncan's multiple range test.

in June-sown cotton and two to four w.a.s. in July-sown crop, respectively. Once these plots were kept weed-free initially for six w.a.s. no detectable subsequent weed growth was observed.

As shown in Tables 14 and 16, in both June and July-sown cotton, weed dry matter production was negatively and significantly correlated with plant height, frame dry weight, boll numbers, boll dry weight and seed cotton yield.

B. Weed control study (Experiment II)

1. Crop yield components

a. Stand count

In June-sown and July-sown cotton stand count was neither affected by nitrogen application nor weed control treatments, as observed in Table 16.

b. Crop vigour

Crop vigour score at 12 w.a.s. was not significantly affected by planting date. It was however, affected significantly by nitrogen levels and weed control treatments. Cotton vigour score increased with increase in nitrogen levels. All the weed control treatments resulted in higher vigour score than the unweeded check (Table 17). In spite of the supplementary hoe-weeding done at six weeks after sowing, fluridone plus diuron at low rate; norflurazon plus diuron at both rates resulted in significantly lower scores than hoe-weeded control. Crop vigour

Table 14: Correlation matrix for seed cotton yield and yield of cotton sown in June, 1981.

	2	3	4	5	6	7	8
1. Seed cotton yield	-.614*	.462	.913**	.821**	.931**	.47	.877**
2. Weed weight							
3. Stand count							
4. Boll count	-.752**			.930**			
5. Plant height	-.803**						
6. Leaf dry weight	-.716**		.908**	.800**			
7. Leaf dry weight	-.299			.254			
8. Frame dry weight	-.691**			.762**			

Table 15: Correlation matrix for seed cotton yield and yield components of cotton sown in July, 1981.

	2	3	4	5	6	7	8
1. Seed cotton yield	-.678*	-.194	.971**	.914**	.909**	.251	.898**
2. Weed weight							
3. Stand count							
4. Boll count	-.680*			.865**			
5. Plant height	-.842**						
6. Boll dry weight	-.558*		.900**	.757**			
7. Leaf dry weight	-.027			.108			
8. Frame dry weight	-.781*			.939**			

** = Significant at one per cent (P = 0.01)

* = Significant at five per cent (P = 0.05)

Table 16: Effect of sowing dates, nitrogen levels and weed control treatments on stand count in cotton, at harvest.

Treatments	Control stand ha^{-1}
a. Main-plot	
(i) Sowing dates	
D_1 : June	31,900
D_2 : July	31,700
S.Em.($\pm$)	533
L.S.D. (P = 0.05)	Not significant
(ii) Nitrogen levels (kg ha^{-1})	
N_0 : 0	32,133
N_1 : 30	31,600
N_2 : 60	31,700
S.Em.($\pm$)	533
L.S.D. (P = 0.05)	Not significant
b. Sub-plot	
Weed control treatments	
W_1 : Flur. + Diu. @ 0.4 + 0.4 kg	31,100
W_2 : Flur. + Diu. @ 0.8 + 0.8 kg	31,333
W_3 : Nor. + Diu. @ 0.4 + 0.4 kg	31,733
W_4 : Nor. + Diu. @ 0.8 + 0.8 kg	31,900
W_5 : Two hoe weedings (3 & 5 w.a.s)	31,200
W_6 : Unweeded check	31,200
S.Em.($\pm$)	667
L.S.D. (P =00.05)	Not significant
Interaction	Not significant

@ = All herbicides are in kg a.i. ha^{-1}

Diu. = Diuron; Flur. = Fluridone; Nor. = Norflurazon.

score in fluridone plus diuron at 0.8 + 0.8 kg ha^{-1} was similar to that in the hoe-weeded plot. There were no significant interaction effects on the vigour score.

c. Plant height

Plant height increased significantly with nitrogen levels (Table 18). All the weed control treatments resulted in significantly taller cotton plants than the unweeded control. Plant height in hoe-weeded plots were similar to fluridone plus diuron at the two rates used in this study. The low rates of the herbicide mixtures had significantly shorter plants than their corresponding high rates. No significant interaction was observed among the sowing dates, nitrogen levels and weed control treatments.

d. Leaf dry weight

As shown in Table 19 June-sown cotton produce significantly higher leaf dry matter per stand at 22 w.a.s. than the July-sown crop. Although the effect of nitrogen on leaf dry matter was not significant, there was a tendency for it to increase with nitrogen levels. Weed control treatments had significant effect on leaf dry matter production and the highest production was obtained with the hoe-weeded control. Fluridone plus diuron at 0.8 + 0.8 kg a.i. ha^{-1} had significantly higher leaf dry matter production than the other herbicide

Table 18: Effect of sowing dates, nitrogen levels and weed control treatments on cotton plant height, ten weeks after sowing.

Treatments	Plant height in cm
a. Main-plot	
(i) Sowing dates	
D_1 : June	66.1
D_2 : July	66.8
S.Em.($\pm$)	1.8
L.S.D. (P = 0.05)	Not significant
(ii) Nitrogen levels (kg ha^{-1})	
N_1 : 0	49.9
N_2 : 30	70.6
N_3 : 60	78.7
S.Em.($\pm$)	2.2
L.S.D. (P = 0.05)	6.5
b. Sub-plot	
Weed control treatments	
W_1 : Flur. + Diu. @ 0.4 + 0.4 kg	71.7
W_2 : Flur. + Diu. @ 0.8 + 0.8 kg	80.7
W_3 : Nor. + Diu. @ 0.4 + 0.4 kg	58.9
W_4 : Nor. + Diu. @ 0.8 + 0.8 kg	67.2
W_5 : Two hoe weedings (3 & 9 w.a.s)	76.5
W_6 : Unweeded check	43.5
S.Em.($\pm$)	2.2
L.S.D. (P = 0.05)	6.0
Interaction	Not significant

@ = All herbicides are in kg a.i. ha^{-1}

Diu. = Diuron; Flur. = Fluridone; Nor. = Norflurazon.

Table 19: Effect of sowing dates, nitrogen levels and control treatments on leaf dry weight (g) per stand in cotton, 22 weeks after sowing.

Treatments	g per stand
a. Main-plot	
(i) Sowing dates	
D_1 : June	4.50
D_2 : July	2.01
S.Em.(±)	0.36
L.S.D. (P = 0.05)	1.35
(ii) Nitrogen levels (kg ha^{-1})	
N_0 : 0	2.70
N_1 : 30	3.30
N_2 : 60	3.70
S.Em.(±)	0.45
L.S.D. (P = 0.05)	Not significant
b. Sub-plot	
Weed control treatments	
W_1 : Flur. + Diu. @ 0.4 + 0.4 kg	2.70
W_2 : Flur. + Diu. @ 0.8 + 0.8 kg	4.60
W_3 : Nor. + Diu. @ 0.4 + 0.4 kg	2.70
W_4 : Nor. + Diu. @ 0.8 + 0.8 kg	2.70
W_5 : Two hoe weedings (3 & 9 w.a.s)	6.40
W_6 : Unweeded check	1.40
S.Em.(±)	0.50
L.S.D. (P = 0.05)	1.40
Interactions	
D x W	Significant
N x W	Significant

@ = All herbicides are in kg a.i. ha^{-1}

Diu. = Diuron; Flur. = Fluridone; Nor. = Norflurazon.

treatments and lower than the hoe-weeded control. There was no significant interaction among sowing date, nitrogen levels and weed control treatments on leave dry weight of cotton.

e. Frame dry weight

The frame dry weight of cotton crop was not significantly affected by sowing date (Table 20). It however, increased significantly with the levels of applied nitrogen. The effect of various weed control treatments on cotton frame weight was also significant. All the treated plots produced higher frame weight than the unweeded control. Fluridone plus diuron 0.8 + 0.8 kg a.i. ha^{-1} and hoe-weeding resulted in similar frame dry weights which were significantly higher than the other weed control treatments.

There were significant interactions between sowing dates and weed control treatments; and nitrogen and weed control treatments. In the June-sown cotton, all the weed control treatments except fluridone plus diuron at 0.8 + 0.8 kg a.i. ha^{-1} had significantly lower frame weight than the hoe-weeded control (Table 21). Fluridone plus diuron at 0.8 + 0.8 kg a.i. ha^{-1}, also produced significantly higher frame weight than the norflurazon + diuron, and unweeded control treatments. In July-sown cotton, fluridone plus diuron at both rates and norflurazon plus diuron at 0.8 + 0.8 kg a.i. ha^{-1} had comparable frame

Table 20: *Effect of sowing dates, nitrogen levels and weed control treatments on frame dry weight (g) per stand in cotton, 22 weeks after sowing.*

Treatments	g per stand
a. Main-plot	
(i) Sowing dates	
D_1 : June	26.2
D_2 : July	22.9
S.Em.(±)	2.0
L.S.D. (P = 0.05)	Not significant
(ii) Nitrogen levels (kg ha^{-1})	
N_0 : 0	11.7
N_1 : 30	26.2
N_2 : 60	34.2
S.Em.(±)	2.4
L.S.D. (P = 0.05)	7.4
b. Sub-plot	
Weed control treatments	
W_1 : Flur. + Diu. @ 0.4 + 0.4 kg	25.7
W_2 : Flur. + Diu. @ 0.8 + 0.8 kg	32.9
W_3 : Nor. + Diu. @ 0.4 + 0.4 kg	19.2
W_4 : Nor. + Diu. @ 0.8 + 0.8 kg	23.7
W_5 : Two hoe weedings (3 & 9 w.a.s)	36.2
W_6 : Unweeded check	6.3
S.Em.(±)	1.9
L.S.D. (P = 0.05)	5.3
Interactions	
D x W	Significant
N x W	Significant

@ = All herbicides are in kg a.i. ha^{-1}

Diu. = Diuron; Flur. = Fluridone; Nor. = Norflurazon.

Table 21: The interaction effect of sowing dates and weed control treatments on frame dry weight (g) per stand in cotton, 22 weeks after sowing.

Weed control treatments	Sowing dates June	July
	(g)per stand	
Flur. + Diu. @ 0.4 + 0.4 kg	28.9	22.6
Flur. + Diu. @ 0.8 + 0.8 kg	36.2	29.6
Nor. + Diu. @ 0.4 + 0.4 kg	21.4	17.1
Nor. + Diu. @ 0.8 + 0.8 kg	21.2	26.3
Two hoe weedings (3 & 9 w.a.s)	42.6	29.8
Unweeded check	6.9	5.8
L.S.D. (P = 0.05)	7.5	

Table 22: The interaction effect of nitrogen levels and weed control treatments on frame dry weight (g) per stand of cotton, 22 weeks after sowing.

Weed control treatments	Nitrogen levels kg ha^{-1} 0	30	60
	g per stand		
Flur. + Diu. @ 0.4 + 0.4 kg	10.4	29.9	36.9
Flur. + Diu. @ 0.8 + 0.8 kg	18.5	31.2	49.1
Nor. + Diu. @ 0.4 + 0.4 kg	8.1	20.0	29.6
Nor. + Diu. @ 0.8 + 0.8 kg	12.0	26.1	33.1
Two hoe weedings (3 & 9 w.a.s)	17.4	43.3	47.9
Unweeded check	3.9	6.6	8.5
L.S.D. (P = 0.05)		9.2	

@ = All herbicides are in kg a.i. ha^{-1}.

Diu. = Diuron; Flur. = Fluridone;

Nor. = Norflurazon.

weight to hoe-weeded control; the low rate of norflurazon plus diuron mixture had lower weight than the corresponding high rate. With hoe-weeding twice and fluridone plus diuron at 0.8 + 0.8 kg a.i. ha^{-1}, June-sown cotton had significantly higher frame weight compared with the July-sown crop.

In all the weed control treatments, significant increase in frame weight was obtained with 30 kg N ha^{-1} compared with no nitrogen. Significant frame weight increase with nitrogen levels up to 60 kg N ha^{-1} only occured with fluridone plus diuron at 0.8 + 0.8 kg a.i. ha^{-1} (Table 22). Under unfertilized condition only hoe-weeding twice and fluridone plus diuron at high rate had significantly higher frame dry matter production than the untreated control. When 30 kg N ha^{-1} was applied, frame weight of the hoe-weeded control was higher than those of the other treatments. Fluridone plus diuron at both rates had higher frame weight than norflurazon plus diuron at 0.4 + 0.4 kg ha^{-1}. When 60 kg N ha^{-1} was applied, all the weeded plots resulted in higher frame dry weight compared with the untreated control. Fluridone plus diuron at 0.8 + 0.8 kg a.i. ha^{-1} and hoe-weeding had higher frame weight than the other herbicide treatments.

f. Flower count

The number of cotton flowers, at 11 weeks after sowing, was significantly higher in June-sown crop than that of July-sown crop (Table 23).

Flower count increased significantly with the levels of applied nitrogen. The effect of weed control treatments on the number of flowers produced was also significant. All the weed control treatments resulted in much higher number of flowers than the unweeded check. Norflurazon plus diuron at both rate however produced lower number of flowers than the hoe-weeded control. Fluridone plus diuron at 0.4 + 0.4 kg a.i. ha^{-1} was comparable to heo-weeding while higher rate of these herbicides (0.8 + 0.8 kg ha^{-1}) produced significantly more flowers than both the hoe-weeded treatment and the lower rates.

The interaction effects of weed control treatments with sowing dates and nitrogen levels on flower count were significant. Table 24 reveals that in the June-sown cotton, all weed control treatments, except fluridone plus diuron at 0.8 + 0.8 kg a.i. ha^{-1}, resulted in significantly lower flower count than the hoe-weeded control; while in July-sown cotton only the lower rate of norflurazone + diuron (0.4 + 0.4 kg ha^{-1}) was inferior to hoe-weeding. Fluridone plus diuron at 0.8 + 0.8 kg a.i. ha^{-1} produced

Table 23: Effect of sowing dates, nitrogen levels and weed control treatments on the number of flowers per stand in cotton, 11 weeks after sowing.

Treatments	Flower number per stand
a. Main-plot	
(i) Sowing dates	
D_1 : June	10.4
D_2 : July	8.3
S.Em.(±)	0.3
L.S.D. (P = 0.05)	0.8
(ii) Nitrogen levels (kg ha^{-1})	
N_0 : 0	6.7
N_1 : 30	9.8
N_2 : 60	11.6
S.Em.(±)	0.3
L.S.D. (P = 0.05)	1.0
b. Sub-plot	
Weed control treatments	
W_1 : Flur. + Diu. @ 0.4 + 0.4 kg	11.1
W_2 : Flur. + Diu. @ 0.8 + 0.8 kg	13.6
W_3 : Nor. + Diu. @ 0.4 + 0.4 kg	8.5
W_4 : Nor. + Diu. @ 0.8 + 0.8 kg	9.3
W_5 : Two hoe weedings (3 & 9 w.a.s)	11.8
W_6 : Unweeded check	1.7
S.Em.(±)	0.4
L.S.D. (P = 0.05)	1.2
Interactions	
D x W	Significant
N x W	Significant

@ = All herbicides are in kg a.i. ha^{-1}.

Diu. = Diuron; Flur. = Fluridone; Nor. = Norflurazon.

Table 24: The interaction effect of sowing dates and weed control treatments on the number of flowers per stand in cotton, 11 weeks after sowing.

..eed control treatments	Sowing dates	
	June	July
	No. per stand	
Flur. + Diu. @ 0.4 + 0.4 kg	9.4	12.8
Flur. + Diu. @ 0.8 + 0.8 kg	12.0	15.1
Nor. + Diu. @ 0.4 + 0.4 kg	7.2	9.7
Nor. + Diu. @ 0.8 + 0.8 kg	7.4	11.2
Two hoe weedings (3 & 9 w.a.s)	12.2	11.4
Unweeded check	1.6	1.9
L.S.D. (P = 0.05)	1.7	

Table 25: The interaction effect of nitrogen levels and weed control treatments on the number of flowers per stand in cotton, 11 weeks after sowing.

Weed control treatments	Nitrogen levels in kg ha^{-1}		
	0	30	60
	No. per stand		
Flur. + Diu. @ 0.4 + 0.4 kg	7.9	11.5	13.8
Flur. + Diu. @ 0.8 + 0.8 kg	11.7	14.6	14.5
Nor. + Diu. @ 0.4 + 0.4 kg	5.3	9.5	10.6
Nor. + Diu. @ 0.8 + 0.8 kg	6.4	9.1	12.5
Two hoe weedings (3 & 9 w.a.s)	8.0	12.[illegible]	15.4
Unweeded check	0.9	1.7	2.6
L.S.D. (P = 0.05)		2.1	

highest number of flowers in the cotton crop sown in July. Generally, at comparable rates, the fluridone containing mixture resulted in higher flower counts than the norflurazon plus diuron.

With increase in nitrogen levels from 0 to 30 kg ha^{-1} there was significant increase in flower count in all the weed control treatments including even the unweeded check (Table 25). With further increased in nitrogen level from 30 to 60 kg ha^{-1}, there was also increase in flower count but this was not significant in fluridone plus diuron treatment at 0.8 + 0.8 kg a.i. ha^{-1} and norflurazone + diuron at 0.4 + 0.4 kg a.i. ha^{-1}. Significantly highest flower count was observed as a result of hoe-weeding at the 60 kg N ha^{-1} treatment. This was similar to fluridone + diuron mixture (0.8 + 0.8 kg a.i. ha^{-1}) treatment at the nitrogen levels of 30 and 60 kg ha^{-1}.

g. Boll number per stand

As indicated in Table 26, June-sown cotton produced significantly higher number of bolls per stand at 18 w.a.s. than the July-sown crop. Application of 30 kg N ha^{-1} increased the number of bolls per stand significantly and no further increase was observed with 60 kg N ha^{-1}. Weed control treatments significantly affected boll number per cotton stand. All the treated plots

Table 26: Effect of sowing dates, nitrogen levels and weed control treatments on boll number per stand in cotton, 18 weeks after sowing.

Treatments	Boll number per stand
a. Main-plot	
(i) Sowing dates	
D_1 : June	10.5
D_2 : July	9.0
S.E.m(±)	0.4
L.S.D. (P = 0.05)	1.1
(ii) Nitrogen levels (kg ha^{-1})	
N_0 : 0	7.8
N_1 : 30	10.3
N_2 : 60	11.1
S.Em.(±)	0.5
L.S.D. (P = 0.05)	1.4
b. Sub-plot	
Weed control treatments	
W_1 : Flur. + Diu. @ 0.4 + 0.4 kg	10.9
W_2 : Flur. + Diu. @ 0.8 + 0.8 kg	12.0
W_3 : Nor. + Diu. @ 0.4 + 0.4 kg	8.9
W_4 : Nor. + Diu. @ 0.8 + 0.8 kg	10.0
W_5 : Two hoe weedings (3 & 9 w.a.s)	12.0
W_6 : Unweeded check	1.7
S.E.m(+)	3.0
L.S.D. (P = 0.05)	8.3
Interactions	Not significant

@ = All herbicides are in kg a.i. ha^{-1}

Diu. = Diuron; Flur : Fluridone; Nor. = Norflurazon.

with the exception of norflurazon plus diuron at 0.4 + 0.4 kg a.i. ha^{-1} produced significantly greater number of bolls per stand compared to the unweeded check. About 84.6 per cent reduction in boll number was obtained with the unweeded control compared with the best herbicide treatments. The number of bolls produced in all the herbicide treated plots did not differ significantly from each other. The interactions among sowing dates, nitrogen levels and weed control treatments were not significant.

h. Boll dry weight

June-sown cotton, resulted in significantly higher boll dry weight at 22 w.a.s. than the July-sown crop (Table 27). As observed with boll number at 18 w.a.s. application of 30 and 60 kg N ha^{-1} increased boll dry weight over no nitrogen treatment, however, no increase in boll dry weight was observed when nitrogen level was increased from 30 kg N to 60 kg N ha^{-1}. All the weed control treatments resulted in significantly more boll dry weight than the unweeded control. Hoe-weeding resulted in significantly higher boll dry weight than the herbicide treatments. Norflurazon plus diuron at 0.4 + 0.4 kg a.i. ha^{-1} produced a significantly lower boll dry weight than other herbicide treatments except fluridone plus diuron at 0.4 + 0.4 kg a.i. ha^{-1}.

Table 27: Effect of sowing dates, nitrogen levels and weed control treatments on boll dry weight (g) per stand in cotton, 22 weeks after sowing.

Treatments	g per stand
a. Main-plot	
(i) Sowing dates	
D_1 : June	53.9
D_2 : July	40.9
S.Em.(±)	2.2
L.S.D. (P = 0.05)	6.6
(ii) Nitrogen levels (kg ha^{-1})	
N_0 : 0	34.2
N_1 : 30	50.3
N_2 : 60	57.7
S.Em.(±)	2.7
L.S.D. (P = 0.05)	8.0
b. Sub-plot	
Weed control treatments	
W_1 : Flur. + Diu. @ 0.4 + 0.4 kg	51.6
W_2 : Flur. + Diu. @ 0.8 + 0.8 kg	57.7
W_3 : Nor. + Diu. @ 0.4 + 0.4 kg	44.2
W_4 : Nor. + Diu. @ 0.8 + 0.8 kg	54.7
W_5 : Two hoe weedings (3 & 9 w.a.s)	68.5
W_6 : Unweeded check	7.7
S.Em.(±)	3.3
L.S.D. (P = 0.05)	9.1
Interactions	
D x N	Significant
D x W	Significant
D x N x W	Significant

@ = All herbicides are in kg a.i. ha^{-1}.

Diu. = Diuron; Flur. = Fluridone; Nor. = Norflurazon.

Significant interactions were observed between sowing dates and nitrogen, sowing date and weed control treatments, and among date of sowing, nitrogen level and weed control treatments. There was a significant increase in boll dry weight with nitrogen levels in June-sown cotton while in July-sown crop application of 30 kg N and 60 kg N resulted in similar increase over nitrogen (Table 28). Boll dry weight per stand in June and July-sown crops were similar when cotton was grown without nitrogen application. But when 30 and 60 kg N ha^{-1} were applied to cotton, June-sown crop produced higher boll dry weight than the July-sown.

In Table 29, it was observed that in June-sown cotton, hoe-weeding and fluridone plus diuron at 0.8 + 0.8 kg a.i. ha^{-1} produced significantly higher boll dry weight per stand than the other weed control treatments. While in July-sown cotton only norflurazon plus diuron 0.4 + 0.4 kg a.i. ha^{-1}, and unweeded control resulted in lower boll weight than the hoe-weeded control.

In the June-sown crop, high rate of fluridone plus diuron mixture resulted in higher boll dry weight than the low rate, and this was significant at 60 kg N ha^{-1} (Table 30). Without nitrogen application, only norflurazone plus diuron at low rate gave significantly lower boll dry weight than the hoe-weeded control, while only

Table 30: The interaction effect of sowing dates, nitrogen levels and weed control treatments on boll dry weight (g) per stand in cotton, 22 weeks after sowing.

Weed control treatments	Sowing dates					
	June			July		
	N in kg ha^{-1}			N in kg ha^{-1}		
	0	30	60	0	30	60
	(g per stand)					
Flur. + Diu. @ 0.4 + 0.4 kg	38.7	58.4	76.0	33.2	52.1	51.2
Flur. + Diu. @ 0.8 + 0.8 kg	47.2	68.4	97.5	54.8	43.1	35.1
Nor. + Diu. @ 0.4 + 0.4 kg	21.8	46.2	83.1	28.3	45.8	40.2
Nor. + Diu. @ 0.8 + 0.8 kg	38.2	63.0	62.2	36.3	53.2	75.3
Two hoe weedings (3 & 9 w.a.s)	89.9	90.1	95.7	45.2	67.4	52.8
Unweeded check	3.0	9.6	10.7	4.0	6.9	12.2
L.S.D. (P = 0.05)	22.3					

the high rate of this herbicide mixture produced lower boll weight at 60 kg N ha^{-1}. In July-sown cotton, high rate of norflurazon plus diuron mixture resulted in more boll dry matter production than that of its low rate; this improved with nitrogen levels, and was significantly high at 60 kg N ha^{-1}. Without nitrogen, all the herbicide treatments had comparable boll weights to the hoe-weeded control. However, with the application of 30 and 60 kg N ha^{-1}, lowest boll dry weight of cotton was obtained with high rate of fluridone plus diuron mixture, while at 60 kg N ha^{-1}, boll dry weight with norflurazon plus diuron at 0.8 + 0.8 kg a.i. ha^{-1} was higher than those of other weed control treatments.

i. Seed cotton yield

The effect of date of sowing on seed cotton yield was not significant, although June-sown crop showed a tendency to yield slightly higher than the July-sown (Table 31).

Seed cotton yield increased significantly with increase in nitrogen levels. All the weed control treatments resulted in higher seed cotton yield than the unweeded check. Fluridone plus diuron treatments were comparable to hoe-weeded control but higher than norflurazon plus diuron treatments.

As shown in Table 32, in the June-sown cotton, fluridone plus diuron at high rate (0.8 + 0.8 kg

Table 31: Effect of sowing dates, nitrogen levels and weed control treatments on seed cotton yield in kg ha^{-1}.

Treatments	Seed cotton (kg ha^{-1})
a. Main-plot	
(i) Sowing dates	
D_1 : June	1082.8
D_2 : July	938.9
S.Em.($\pm$)	48.0
L.S.D. (P = 0.05)	Not significant
(ii) Nitrogen levels (kg ha^{-1})	
N_0 : 0	774.7
N_1 : 30	1036.3
N_2 : 60	1222.8
S.Em.($\pm$)	58.8
L.S.D. (P = 0.05)	182.0
b. Sub-plot	
Weed control treatments	
W_1 : Flur. + Diu. @ 0.4 + 0.4 kg	1257.1
W_2 : Flur. + Diu. @ 0.8 + 0.8 kg	1341.0
W_3 : Nor. + Diu. @ 0.4 + 0.4 kg	894.8
W_4 : Nor. + Diu. @ 0.8 + 0.8 kg	978.4
W_5 : Two hoe weedings (3 & 9 w.a.s)	1370.1
W_6 : Unweeded check	224.4
S.Em.($\pm$)	60.3
L.S.D. (P = 0.05)	171.6
Interactions	
D x W	Significant

@ = All herbicides are in kg a.i. ha^{-1}.

Diu. = Diuron; Flur. = Fluridone; Nor. = Norflurazon.

Table 32: The interaction effect of sowing dates and weed control treatments on seed cotton yield (kg ha^{-1}).

Weed control treatments	Sowing dates June	July
	kg ha^{-1}	
Flur. + Diu. @ 0.4 + 0.4 kg	1213.7	1236.5
Flur. + Diu. @ 0.8 + 0.8 kg	1410.6	1203.1
Nor. + Diu. @ 0.4 + 0.4 kg	928.6	815.4
Nor. + Diu. @ 0.8 + 0.8 kg	945.3	961.6
Two hoe weedings (3 & 9 w.a.s)	1570.9	1099.5
Unweeded check	263.8	173.4
L.S.D. (P = 0.05)	242.6	

ha^{-1}) resulted in comparable seed cotton yield to hoe-weeded control, while in the July-sown both rates of fluridone plus diuron had similar yields with the hoe-weeded control. In both dates of sowing, seed cotton yields with fluridone plus diuron mixtures were higher than those of norflurazon plus diuron. A signficantly high difference was obtained when the seed cotton yields for both sowing dates in all the weed control treatments were compared with their unweeded check.

2. Weed growth

a. Weed flora

Weed species that dominated the experimental site for June-sown and July-sown cotton are listed below together with their percentage distribution.

Weed species	June-sown	July-sown
Cynodon dactylon	50%	20%
Cyperus esculenthus	15%	5%
Cyperus rotundus	10%	5%
Ageratun conyzoides	5%	20%
Acanthospermum hispidium	5%	20%
Mikania cordata	10%	15%
Commelina benghalensis		5%
Others	5%	10%

b. Weed cover score

At nine w.a.s., the plots of July-sown cotton had significantly lower weed-score than those of June-sown crop, while nitrogen application did not significantly affect the weed score (Table 33). All the weed control treatments, however resulted in significantly lower score than the unweeded control. Fluridone plus diuron at 0.8 + 0.8 kg a.i. ha^{-1} had the lowest weed score at nine w.a.s., while the low rate of the mixture was comparable to the hoe-weeded control, but significantly lower than those of norflurazon plus diuron at both rates.

The interactions between sowing dates and weed control treatments, weed control treatments and nitrogen level were also significant. As shown in Table 34, lower weed score was recorded in the July-sown crop than June-sown in the herbicide-treated and the unweeded plots, while higher weed score was recorded in the July-sown cotton on the hoe-weeded plots. In the June-sown crop, fluridone plus diuron at high rate (0.8 + 0.8 kg a.i. ha^{-1}) had comparable score to hoe weeded control, both of which were significantly lower than those of the other weed control treatments including hoe-weeded control.

When no nitrogen was applied (Table 35), all the herbicides had similar scores to the hoe-weeded control, while with 30 and 60 kg N ha^{-1} application

Table 33: Effect of sowing dates, nitrogen levels and weed control treatments on weed score of cotton at three and nine weeks after sowing.

Treatments	Weeks after sowing	
	Three	Nine
	Weed cover score*	
a. Main-plot		
(i) Sowing dates		
D_1 : June	3.9	3.2
D_2 : July	1.1	2.5
S.Em.(±)	0.3	0.1
L.S.D. (P = 0.05)	0.9	0.3
(ii) Nitrogen levels (kg ha^{-1})		
N_0 : 0	3.0	2.7
N_1 : 30	2.2	2.8
N_2 : 60	2.3	3.0
S.Em.(±)	0.4	0.1
L.S.D. (P = 0.05)	Not significant	Not significant
b. Sub-plot		
Seed control treatment		
W_1 : Flur. + Diu. @ 0.4 + 0.4 kg	2.2	1.6
W_2 : Flur. + Diu. @ 0.8 + 0.8 kg	1.7	1.0
W_3 : Nor. + Diu. @ 0.4 + 0.4 kg	2.8	2.9
W_4 : Nor. + Diu. @ 0.8 + 0.8 kg	2.4	2.5
W_5 : Two hoc weedings (3 & 9 w.a.s)	3.0	1.7
W_6 : Unweeded check	2.8	7.4
S.Em.(±)	0.2	0.2
L.S.D. (P = 0.05)	0.6	0.5
Interactions		
D x W	Not significant	Not significant
N x W	Not significant	Not significant

* = Weed score: 0 = no weed cover; 10 = complete ground cover with weeds.

@ = All herbicides are in kg a.i. ha^{-1}.

Diu. = Diuron; Flur. = Fluridone; Nor. = Norflurazon.

Table 34: The interaction effect of sowing dates and weed control treatments on weed socre in cotton, nine weeks after sowing.

Weed control treatments	Sowing dates June	July
	Weed socre*	
Flur. + Diu. @ 0.4 + 0.4 kg	2.2	0.9
Flur. + Diu. @ 0.8 + 0.8 kg	1.4	0.5
Nor. + Diu. @ 0.4 + 0.4 kg	3.3	2.4
Nor. + Diu. @ 0.8 + 0.8 kg	3.3	1.8
Two hoe weedings (3 & 9 w.a.s)	1.1	2.3
Unweeded check	8.0	6.9
L.S.D. (P = 0.05)	0.8	

* = Weed score: 0 is no weed cover and 10 is complete ground cover with weed.

Table 35: The interaction effect of nitrogen levels and weed control treatments on weed score of cotton, nine weeks after sowing.

Weed control treatments	Nitrogen levels, kg ha^{-1} 0	30	60
	Weed score*		
Flur. + Diu. @ 0.4 + 0.4 kg	1.7	1.5	1.5
Flur. + Diu. @ 0.8 + 0.8 kg	1.1	0.8	1.0
Nor. + Diu. @ 0.4 + 0.4 kg	2.6	2.9	3.1
Nor. + Diu. @ 0.8 + 0.8 kg	2.1	2.8	2.6
Two hoe weedings (3 & 9 w.a.s)	2.0	1.3	1.8
Unweeded check	6.6	7.6	8.1
L.S.D. (P = 0.05)	0.95		

* = Weed cover score: 0 is no weed cover and 10 is complete ground cover with weed.

both rates of norflurazon plus diuron mixture had higher scores than the hoe-weeded control.

c. Weed dry weight

Significantly higher weed dry matter production was obtained in July-sown cotton as compared with June-sown (Table 36). The cotton crop that received 30 or 60 kg N ha^{-1} had significantly higher weed dry matter production than the crop without nitrogen application. All the weed control treatments produced lower weed dry matter than the unweeded check. Fluridone plus diuron at both rates and the hoe-weeded control resulted in a significantly lower weed dry matter than both rates of norflurazon plus diuron. Weed dry matter production with low rate of the herbicides was more than that of the corresponding high rate.

Significant interactions, among date of sowing, nitrogen and weed control treatments on weed dry matter production were obtained as shown in Tables 38, 39 and 40.

In June-sown cotton, nitrogen application resulted in significantly higher weed dry matter production as compared to no nitrogen application but not in the July-sown crop. Similarly, without nitrogen application, weed dry matter production was higher in the July-sown cotton than the June-sown crop (Table 37). As shown in Table 38, in all nitrogen levels, fluridone

Table 36: Effect of sowing dates, nitrogen levels and weed control treatments on weedy dry matter (kg ha^{-1}) in cotton at harvest.

Treatments	kg ha^{-1}
a. Main Plot	
(i) Sowing dates	
D_1 : June	1578.8
D_2 : July	1869.6
S.Em.(±)	91.2
L.S.D. (P = 0.05)	274.8
(ii) Nitrogen levels (kg ha^{-1})	
N_0 : 0	1467.6
N_1 : 30	1809.2
N_2 : 60	1896.4
S.Em.(±)	111.7
L.S.D. (P = 0.05)	336.8
b. Sub-plot	
Weed control treatments	
W_1 : Flur. + Diu. @ 0.4 + 0.4 kg	1132.0
W_2 : Flur. + Diu. @ 0.8 + 0.8 kg	772.0
W_3 : Nor. + Diu. @ 0.4 + 0.4 kg	2032.0
W_4 : Nor. + Diu. @ 0.8 + 0.8 kg	1664.0
W_5 : Two hoe weedings (3 & 9 w.a.s)	952.0
W_6 : Unweeded check	3940.0
S.Em.(±)	103.6
L.S.D. (P = 0.05)	287.2
Interactions	
D x N	Significant
N x W	Significant
D x N x W	Significant

@ = All herbicides are in kg a.i. ha^{-1}.

Diu. = Diuron; Flur. = Fluridone; Nor. = Norflurazon.

Table 37: The interaction effect of sowing dates and nitrogen levels on weed dry matter (kg ha^{-1}) in cotton at harvest.

Nitrogen levels in kg ha^{-1}	Sowing dates	
	June	July
	kg ha^{-1}	
0	1192.2	1742.7
30	1680.2	1938.2
60	1864.5	1928.3
L.S.D. (P = 0.05)	476.1	

Table 38: The interaction effect of nitrogen levels and weed control treatments on weed dry matter (kg ha^{-1}) in cotton at harvest.

Weed control treatments	Nitrogen levels in kg ha^{-1}		
	0	30	60
		kg ha^{-1}	
Flur. + Diu. @ 0.4 + 0.4 kg	1099.5	1077.5	1217.5
Flur. + Diu. @ 0.8 + 0.8 kg	798.0	850.5	666.0
Nor. + Diu. @ 0.4 + 0.4 kg	1658.5	2025.5	2409.0
Nor. + Diu. @ 0.8 + 0.8 kg	1476.0	1726.5	1787.0
Two hoe weedings (3 & 9 w.a.s)	1043.5	903.5	908.0
Unweeded check	3153.6	4272.5	4392.5
L.S.D. (P = 0.05)		497.5	

@ = All herbicides are in kg a.i. ha^{-1}.

Diu. = Diuron; Flur. = Fluridone; Nor. = Norflurazon.

plus diuron at high rate (0.8 + 0.8 kg a.i. ha^{-1}) gave a significantly lower weed weight than norflurazon plus diuron at both rates. High rate of fluridone plus diuron mixture also produced lower weed weight than the low rate. Both rates of norflurazon plus diuron mixture had higher weed dry matter production than the hoe-weeded control when nitrogen was applied while in the absence of nitrogen only the low herbicide rate had higher weed weight. In the June-sown cotton, both rates of fluridone plus diuron and the hoe-weeded control had similar weed dry matter which was lower than that of the unweeded control at all nitrogen levels (Table 39). Norflurazon + diuron only produced lower dry matter than the unweeded control when 30 and 60 kg N ha^{-1} were applied. Weed dry matter production with this herbicide treatment was significantly higher than that of the hoe-weeded control at all nitrogen levels in the June-sowing. In the July-sown crop, all the herbicide and hoe-weeded control treatments had similar weed dry matter production on the plots that did not receive nitrogen, while low rate of norflurazon plus diuron produced higher dry matter than that of the hoe-weeded control with both levels of nitrogen. Weed dry matter production with low rate of norflurazon plus diuron was lower when no nitrogen was applied than with 30

Table 39: The interaction effect of sowing dates, nitrogen levels and weed control treatments on weed dry matter (kg ha^{-1}) in cotton at harvest.

Weed control treatments	Sowing dates					
	June			July		
	N in kg ha^{-1}			N in kg ha^{-1}		
	0	30	60	0	30	60
	(kg ha^{-1})					
Flur. + Diu. @ 0.4 + 0.4 kg	1295	1054	776	905	1101	1659
Flur. + Diu. @ 0.8 + 0.8 kg	484	560	684	1112	1141	648
Nor. + Diu. @ 0.4 + 0.4 kg	1732	1568	2236	1585	2483	2582
Nor. + Diu. @ 0.8 + 0.8 kg	1684	1796	1980	1268	1657	1794
Two hoe weedings (3 & 9 w.a.s)	624	545	701	1463	1262	1150
Unweeded check	2184	4560	5013	4123	3985	3772
L.S.D. (P = 0.05)			703.5			

@ = All herbicides are in kg a.i. ha^{-1}

Diu. = Diuron; Flur. = Fluridone; Nor. = Norflurazon.

and 60 kg N ha^{-1}. High rate of fluridone plus diuron produced higher weed dry matter than the two rates of norflurazon plus diuron on the July-sown plots treated with 60 kg N ha^{-1}.

CHAPTER V

DISCUSSION

A. Weed competition study (Experiment I)

1. Weed dry matter production

The weed dry matter production in July-sown cotton was 33 per cent less than that of the June-sown crop (Table 12). This observation is consistant with what was reported by Kumar et al. (1982a) for early-sown cotton. The high biomass production in June-sown plots was due to exposure to longer rainy period, optimum temperature and high relative humidity which were conducive to the rapid growth of weeds as well as crop.

The weed-free period of two w.a.s. reduced weed weight by 76 per cent as compared with the unweeded check. Cotton kept weed-free even for two w.a.s. did not produce significantly more weed weight than the plots kept weed-free throughout the crop cycle. Cotton become competitive enough to compete with weed when given weed-free environment even for the first two weeks. The later emerging weeds are likely to be shaded and supressed in competition by the cotton which is tall and has developed the canopy. The production of weed dry weight is the function of weed density and duration of growth. Unchecked weeds continued to emerge and grow throughout the crop cycle and produced five

and a half times more weed dry weight than in the shortest weed-infested period of two weeks only. The grand growth period of weeds as observed by the most rapid production of weed dry weight occured between six and eight w.a.s. the crop. This indicates that weeds should be removed from the cotton plots six w.a.s. to avert the losses in seed cotton yield (Table 10).

2. Crop growth and yield

June-sown cotton (early-sown) outyielded the July-sown (late-sown) crop by about 48 per cent. Recent reports by Ogunlela *et al*. (1981) and Kumar, *et al*. (1982a and 1982b) have also confirmed the superiority of June-sown cotton over July-sown. This was attributed to the exposure of the June-sown crop to longer rainfall duration, thus allowing for adequate moisture for effective utilization of applied nutrient both for the vegetative growth and the development and maturation of the bolls. This is logical in the northern cotton zone, since planting in June would allow for a longer duration for the reproductive phase of the cotton crop as compared with July-sowing. Samaru 71, the cotton variety used in this experiment, requires about 60 days from planting to flowering and another 55 to 60 days for boll development. It is thus obvious that the June-sown cotton had adequate period in the wet season for boll maturation. July-sown cotton was

only exposed to about 30 days duration of absolute rainfall which was about half that of June-sown crop. Therefore, the boll maturation phase of July-sown cotton probably experienced a moisture stress due to cessation of rains as also reported by Kowal and Faulkner (1975) which has resulted in the production of immature bolls. Even a low density of weed-infestation have aggrevated the moisture stress and added to reduction in seed cotton yield of the July-sown crop.

At the initial stages of growth, both crop and weed have adequate of space, nutrients and water relative to their requirements, hence crop is not affected (Marthinez and Nieto, 1968). This was further confirmed in this study where association of weeds with the cotton crop for the first six weeks did not adversely affect plant height, number and dry weight of bolls and seed cotton yield as compared to weed-free check (Tables 5, 8, 9 and 10 respectively. Similarly, Miller, et al. (1961), Smith and Brown (1963), Buchanan, et al. (1973) and Okafor (1982) observed that though cotton has a slow growth habit at the initial stage, the crop is tolerant to weed competition for the first four to six w.a.s. However leaf dry matter in this experiment was not reduced by weed-infestations until ten w.a.s. This was probably because for a certain period when both crop and weeds

were competing for light, cotton might have shown enhanced vegetative growth (Patterson, et al. (1980) which later had adverse effect on yield. It was observed that weed-infestation during the first eight and ten weeks of crop growth caused a seed cotton yield reduction of 62 and 64 per cent, respectively, while weed-infestation throughout resulted in a total yield reduction of 98 per cent. The reduction in seed cotton yield which occured when weeds were allowed to grow with cotton for a period of more than six w.a.s. was expected. This coincided with the initiation of square and pre-blooming stage in cotton and period of grand growth stage in weeds. Perhaps shading effects by weeds were important factors in reducing flower set and subsequently the yield components and the seed cotton yield (Kerkhoven, 1964).

Weeds that emerged after cotton is established (usually six w.a.s.) cause less competition (Thomas and Schwerzel, 1968) since established cotton can effectively exploit the climatic, edaphic and biotic factors available to both crop and weeds to its advantage. In general, seed cotton yield was not reduced once the crop was kept weed-free till six w.a.s. Cotton crop has a slow growth rate in the beginning (Kumar, et al., 1982a and 1982b) and a weed-free period of four w.a.s. was not enough to protect the crop from weed losses. Weed-free period for two and

four w.a.s. caused significant seed cotton yield reduction of 65 and 48 per cent respectively, while no significant loss was obtained with the crop kept weed-free until 6 w.a.s. It was apparent that a weed dry weight of 1.3 and 2 t ha^{-1} in the plot kept weed-free for two and four w.a.s. (Table 11) had adversely affected the crop vigour (Table 3) and production of frame weight (Table 6) flowers (Table 7) and boll which might be the reason of reduced seed cotton yield. Reduction in growth and yield of cotton with presence of weeds for various periods have been reported by Beltrao, et al. (1979) and Petterson, et al. (1980). Cumulative weed weight showed an inverse relationship between seed cotton yield and weed yield (Tables 10 and 12). A negative correlation between weed weight and seed cotton yield was also reported by Kumar, et al. (1982a). Early weed removal aided cotton stand establishment but weed-free environment for the first six w.a.s. was the most critical in obtaining cotton yields as high as in weed-free plots.

3. Critical period of weed competition

In June-sown cotton, when the crop was kept weed-free until six w.a.s. or weed-infested for the first four weeks only, reduction in seed cotton yield was not significant (Table 11). July-sown cotton kept weed-free for first four weeks or weed-infested for six w.a.s. produced seed cotton yield as good as in

the weed-free plots. A significant negative correlation existed between seed cotton yield and weed dry matter production in both the sowing dates of cotton Tables 14 and 15). Significant reduction in dry matter of weeds was observed with June-sown cotton was kept weed-free for four w.a.s. or weed-infested for six w.a.s. (Table 13). Therefore, it appears that a critical period of weed competition in June-sown cotton occurs between four and six w.a.s. (Plates 1 and 2). In July-sown cotton decreased weed dry matter was recorded when the crop was weed-free for the first two weeks or weed-infested until six w.a.s. It was observed that broad leaf weeds dominated the July-sown crop. Kumar, et al. (1982b) have also observed that broad leaf weeds constituted more than 80 per cent of the total weed yield and population during later part of the growing season of cotton at Samaru. The dominant broad leaf weeds with tap root system (similar to cotton) and tall growing habit proved more competitive in July-sown crop. The weeds had aversely affected the seedling establishment, vegetative growth, flower set and boll maturation right from the beginning. Therefore, the critical period of weed competition in July-sown cotton if measured by reduction in seed cotton yield was not well defined though more yield reductions were between two and six w.a.s. (Plates 3 and 4).



Plate I: In June-sown cotton the crop kept weed-infested for four weeks (T_8) or weed-free for six weeks (T_3) was as vigorous as in weed-free throughout (T_6, Plate II) crop life cycle (Photos taken 12 weeks after sowing).

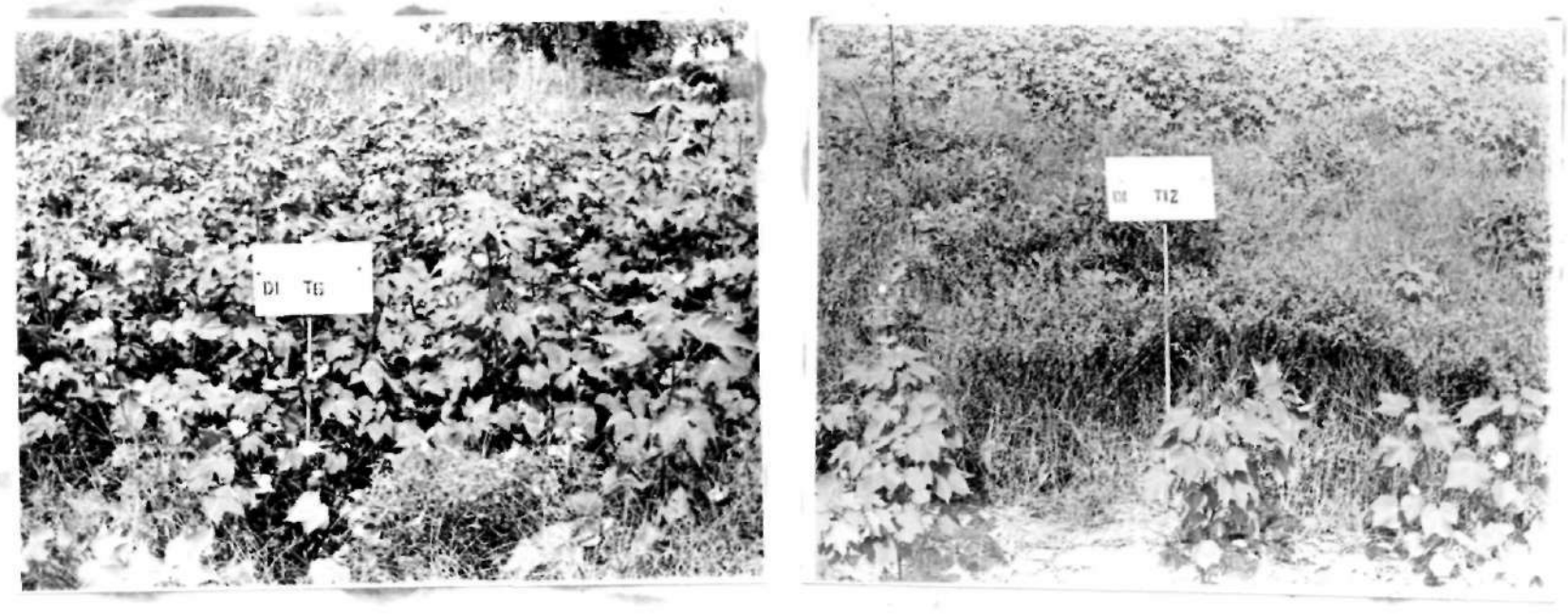


Plate II: In June-sown cotton kept weed-infested throughout (T_{12}) resulted in a luxurient weed growth and consequently poor crop as compared to plants kept weed-free throughout (T_6).

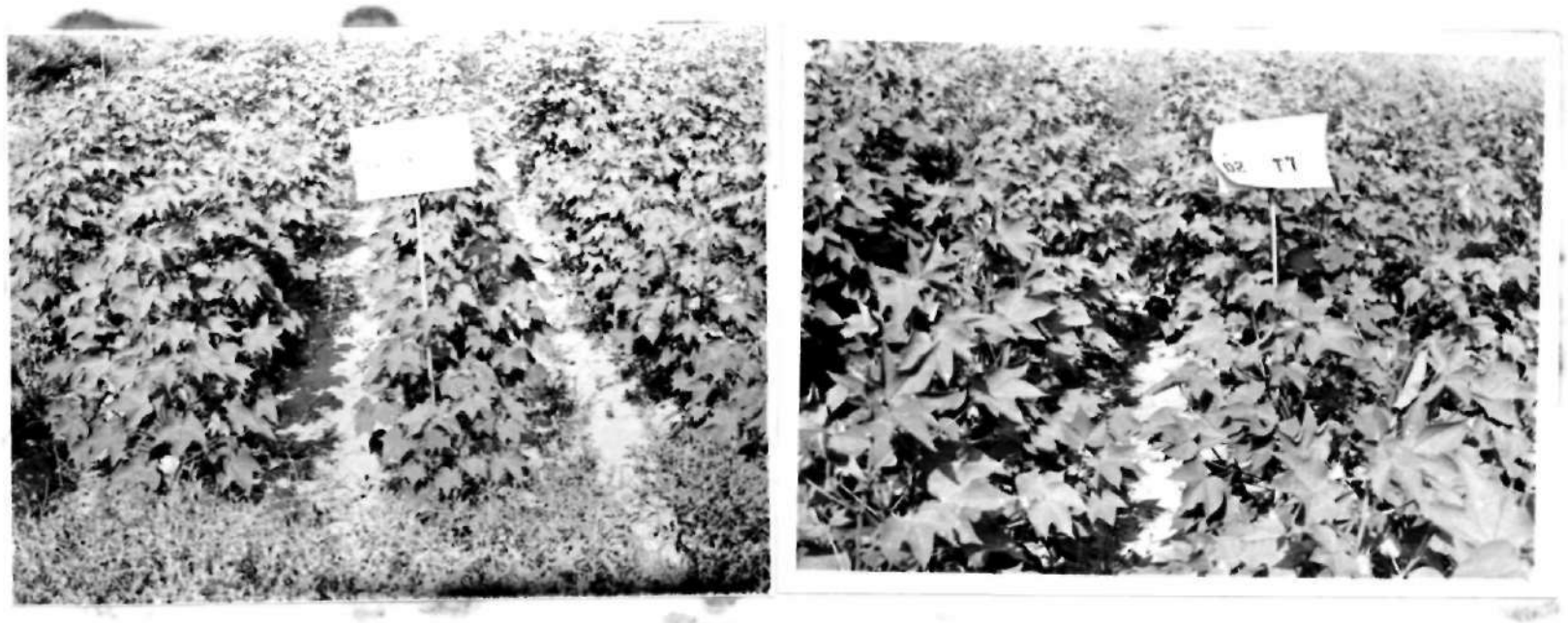


Plate III: In July-sown cotton the crop kept weed-infested for two weeks (T_7) or weed-free for six weeks (T_3) was as vigorous as in weed-free throughout (T_6, Plate IV) the crop life cycle.
(Photos taken nine weeks after sowing).

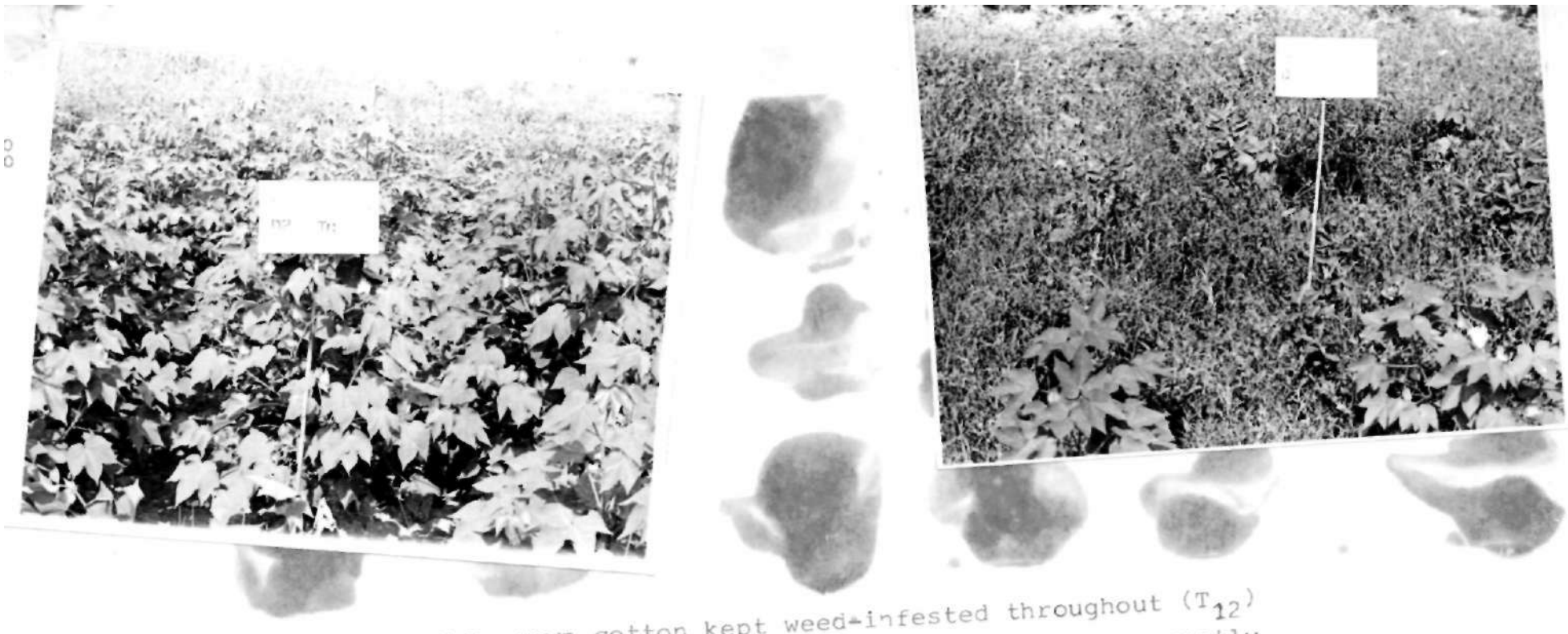


Plate IV: July-sown cotton kept weed-infested throughout (T_{12}) resulted in a luxurient weed growth and consequently poor crop as compared to plants kept weed-free throughout (T_6).

B. Weed control study (Experiment II)

Weed dry matter production in cotton field is affected by weed species (Buchanan, et al., 1973); weed emergence date and duration (Miller, et al., 1961); weed control practices (Buchanan and Burns, 1971); planting date and spacing (Vegris, 1963; Rogers, et al., 1976) and climatic, edaphic and biotic factors (Buchanan and Burns, 1971). Many of these factors were different in the two experiments because of separate fields. Therefore, pattern of weed and seed cotton yields were not similar in the two experiments.

1. Sowing dates

Time of sowing is an important agronomic factor affecting the yield of a crop. In this experiment, June-sowing has favourably affected the growth and the yield contributing characters of cotton crop, though some of these affects are not significant. Such favourable growth of June-sown cotton has been discussed earlier in Experiment I. Despite the higher number of flowers (Table 23) and bolls (Table 24) and high dry weight of bolls, seed cotton yields for the two dates of sowing did not differ significantly It is obvious that more flowers were produced in June-sown cotton and favourably developed to bolls which resulted in higher boll weight. However, I have no separate data for open bolls but it was observed in

the field that in June-sown cotton, the percentage of open bolls was lower than that in July-sown crop. Final seed cotton yield, therefore did not differ significantly in the two sowing dates. This is contrary to our results in Experiment I. Keeley and Thullen (1981) showed that weed competition in cotton is affected by weed species, crop nutrition and weed control practices. Perusal of data in Table 37, shows an increase in weed dry weight with nitrogen application in June-sown cotton which can be responsible for nullifying the impact of boll number and weight on final seed cotton yield.

The effects of different weed control treatments may be partly responsible for non-significant difference in seed cotton yield as observed by interaction between sowing date and weed control treatments (Table 32). The lower weed score obtained in the July-sown plots can be attributed to the late seed bed preparation which destroyed, the emerged and established weeds thus reducing subsequent weed population. Despite lower weed-score, however, final weed weight was higher in July-sown crop robably due to differences in the weed flora (page 69). Broad-leaf weeds which dominated the plots of the July-sown crop have been reported to have higher dry matter production potential than grass weeds (Kumar, et al., 1982a).

2. Nitrogen levels

In this study application of nitrogen increased both the weed and the crop dry matter, since it enhanced the vegetative growth. All the growth parameters such as yield attributes and seed cotton yield increased with nitrogen levels up to 60 kg N ha^{-1} (Tables 4, 28 and 37). Similarly weed dry matter production was increased but only up to 30 kg N ha^{-1} compared with no nitrogen. In effect cotton responded more to increasing nitrogen level than weeds (Tables 28 and 37). Zimdahl (1980) in his review on weed-crop competition concluded that in general, most weed species do not show linear response to nutrients application. Whereas in cotton if nitrogen is abundantly available to crop, there will be increase in the chlorophyll content of the leaves and increase in mitotic activity of the plants (Thomas, et al., 1976). Musa (1969) also observed high weed score as well as increase in seed cotton yield with application of nitrogen. At the same time, Kumar and Kairon (1980) reported that the highest seed cotton yield was obtained when 60 kg N ha^{-1} was applied compared with lower N ha^{-1}.

Boll dry matter increased significantly with increase in nitrogen levels up to 60 kg ha^{-1} in June-sown cotton while this increase was limited to 30 kg N ha^{-1} in July-sown crop (Table 28). This showed that

early-sown cotton has responded to nitrogen during its reproductive phase, whereas the response of the late-sown crop was observed to be marginal as in the finding of Kumar and Ogunlela (1982). Nitrogen fertilizers were band-placed three w.a.s. in close proximity to the crop. The availability of optimum soil moisture due to exposure to longer rainy period probably resulted in efficient utilization of the applied nitrogen in early-sown cotton, as observed by better growth and development of the crop which resulted in significantly higher boll dry matter production under high nitrogen levels. In sowing date and nitrogen interaction (Table 37) weed dry matter production was only significantly increased by 30 kg N ha^{-1} in June-sown crop. This may be attributed to the better response of Cynodon dactylon to nitrogen levels which dominated the plots of June-sown crop than the broad-leaf weeds such as Vernonia spp. which infested the plots of the July-sown crop. The dominant grass species like Cynodon dactylon of June-sown cotton showed a poor dry weight accumulation inspite of longer life cycle. This may be because of the low relative growth rate (R.G.R.) of grasses i.e. Cynodon and Cyperus species as also observed by Frans, et al. (1982) for Cynodon dactylon in cotton. Therefore suppression of Cynodon dactylon with vigorously growing cotton is not unusual. These weeds were eliminated in seed-bed preparation for the

July-sown cotton and subsequent weeds were mainly broad-leaf species as stated on page 69. Initial slow crop growth and later on poor competition ability of crop particularly when rains stopped has favoured the weed weight accumulation in July-sown plots. Snipes, et al. (1982) working on competition of cocklebur with cotton observed that weed being aggressive, proved strong competitor when water supply was limited. In this experiment too July-sown cotton produced high weed dry weight at all nitrogen levels but the differences were significant only at 0 kg N ha^{-1} (Table 37).

3. Weed control treatments

Three of the herbicides viz diuron, fluridone and norflurazon are known to be tolerated well by cotton (Crafts, 1961; Waldrep and Taylor, 1976; Frans, et al., 1982). Field experiment carried out at Samaru (Lagoke and Choudhary, 1982) showed that diuron mixture with fluridone or norflurazon had no injurious effect on cotton crop, hence can be safely used for weed control in cotton. However, weed control efficiency of the two mixtures was different from one another.

Cynodon dactylon infestation was very high in the experimental field and if considered with Cyperus spp. constituted about 75 per cent of the total weed population in June-sown crop (page 69). The high infestation of these pernacious weeds initially precluded the effect

of the herbicide mixtures used in this trial which were mainly effective on annual weeds. All the herbicide-treated plots were therefore given supplementary hoe-weeding at six w.a.s. to remove the pernacious weeds, and improve the performance of the herbicides on weeds. No doubt diuron gives a season long control but only of annual weeds. Already sprouted and perenial grasses are not adversely affected as earlier reported by Bayer and Yamaguchi (1965). Therefore we mixed herbicides to control broad spectrum of weeds infesting a slow growing long season cotton. Fluridone, a new cotton herbicides, control Cynodon dactylon when incorporated into the soil (Anon., 1979). Fluridone plus diuron applied at both rates (0.4 + 0.4 and 0.8 + 0.8 kg a.i. ha^{-1}) subsequently controlled weeds effectively (Plates 5 and 6) and produced seed cotton yields comparable to hoe-weeded control plots. Fluridone plus diuron mixture when applied pre-emergence to cotton was not incorporated in our treatments and that may be the reason that it could not suppress the growth of perenial grasses and sedges. Fluridone is a persistant herbicide and the residues have been reported to be carried over even to the next season (Anon., 1979). In supplementary hoe-weeding done six w.a.s. in herbicide treated plots to remove the existing weeds, an effect like incorporation of already applied herbicides is inevitable. Therefore, more effective control of perennial weeds was



Plate V: In June-sown cotton, under 30 kg N ha^{-1}, fruidone + diuron (0.8 + 0.8 kg a.i. ha^{-1}) and hoe-weeding twice show better control of weeds compared to norflurazon + diuron (0.8 + 0.8 kg a.i. ha^{-1}) and unweeded check (photos at 12 weeks after sowing).



Plate VI: In July-sown cotton, under 30 kg N ha^{-1}, fluridone + diuron (0.8 + 0.8 kg a.i. ha^{-1}) and hoe-weeding twice show excellent control of weeds compared to norflurazone + diuron (0.8 + 0.8 kg a.i. ha^{-1}) and the unweeded check (photos at 12 weeks after sowing).

evident which resulted in high crop vigour score, flower and boll counts, boll weight and consequently seed cotton yield. In contrast, all these parameters were lower with norflurazon plus diuron treatments because of poor weed control despite supplementary hoe-weeding at six w.a.s. Although norflurazon has been reported to give good control of grasses, sedges and rushes (Anon., 1979) it has failed to reduce the re-infestation of Cynodon dactylon as effectively as fluridone containing mixture in this study. However Cynodon spp. regrowth was much suppressed by norflurazon plus diuron which resulted in significantly low weed dry weight as compared to unweeded check. High solubility (24 ppm, double than that of fluridone) along with rapid photo-decomposition and volatilization of norflurazon might be the factors of its relatively poor persistance in soil and responsible for poor control of perennial grasses and sedges as compared with fluridone mixtures. However, the significant improvement of the performance of higher rates of the mixtures on weeds, compared with their low rates, was not truely reflected in the seed cotton yield.

The interaction between sowing dates and weed control treatments indicated that the performance of herbicides was enhanced by the cultivation done in July-sown cotton before planting the crop by effective reduction in the weed-score (Table 34). Late cultivation

for July-sown cotton had reduced weed population by destroying most of the established weeds including the difficult to control types like Cynodon dactylon and Cyperus spp. which in effect reduced their subsequent infestation as this enhanced the performance of the applied herbicide. A weed-free environment is conducive to vigorous crop growth and high plant productivity. In the June-sown cotton, fluridone plus diuron at 0.8 + 0.8 kg a.i. ha^{-1} was required to produce frame and boll dry weights (Tables 21 and 29) and seed cotton yield (Table 32) that were comparable to hoe-weeded control. However in July-sown cotton both rates of fluridone plus diuron (0.4 + 0.4 kg a.i. ha^{-1}) and norflurazon plus diuron at 0.8 + 0.8 kg a.i. ha^{-1} resulted in acceptable weed control and seed cotton yields comparable to hoe-weeded check. In this trial the untreated plots of the July-sown crop were predominantly infested with annual broad-leaf weeds, which were more susceptible to the applied herbicides than Cynodon dactylon and Cyperus spp.

The interaction between nitrogen levels and weed control treatments was similar on weed score (Table 35) and weed dry matter (Table 38). Nitrogen application resulted in significant increase in weed score and weed dry matter in the unweeded plots. Among the weed control treatments such a response was only observed with norflurazon plus diuron at 0.4 + 0.4 kg a.i. ha^{-1}, where

60 kg N ha^{-1} resulted in higher weed dry matter production than zero nitrogen level. Therefore, nitrogen application only favoured weed growth when there was no effective weed control. Interaction effect of flower number (Table 25) reveals that lower rate of fluridone plus diuron mixture under 60 kg N ha^{-1} favourably influenced the production of flowers at rates comparable to the hoe-weeded control, while the high rate had higher flower count at zero and 30 kg N ha^{-1}. This showed that effective control of weeds (Table 38) under high fertility conditions might have favoured the production of more flowers in cotton plants. With effective weed control band placement of nitrogen fertilizer in the close proximity of crop enhanced cotton growth (Tables 17, 19, 20 and 27) rather than that of weed (Buchanan and McLaughlin, 1975).

The interactions between sowing dates, nitrogen levels and weed control treatments were significant only in weed dry matter and boll dry weight. With effective weed control in the hoe-weeded check and high rate of fluridone plus diuron mixture, weed dry matter production in the June-sown cotton under zero and 30 kg N ha^{-1} were lower than those of the corresponding nitrogen treatments in the July-sown crop. This might be due to the fact that June-sown cotton utilized nitrogen more effectively for vigorous growth

than the July-sown crop as indicated earlier. Consequently enhanced vegetative growth in the June-sown crop has smothered the weed growth while adequate nitrogen was still available for active growth of later infesting weeds in the less vigorously growing July crop. Similarly in these weed control treatments, boll dry weights per plant were higher under 30 and 60 kg N ha^{-1} in the June-sown than in the July-sown crop.

CONCLUSION

June-sown cotton outyielded that sown in July by 48 per cent. This was due to longer period of boll development during the wet season. In June-sown cotton, when the crop was kept weed-free for six weeks or weed-infested for not more than four w.a.s., the reduction in seed cotton yield was not significant. The critical period of weed competition with cotton was between four and six w.a.s. In July-sown cotton weed-free for two weeks or weed association for six weeks produced seed cotton yield as good as in the weed-free period until harvest, hence the critical period of weed competition appears to lie between two and six w.a.s., however it is not well defined as in the June-sown cotton. It was observed that weed dry matter production had a negative correlation coefficient

with frame, leaf and boll weights, boll number and plant height respectively.

Cotton crop responded well to 60 kg N ha^{-1} in June-sown crop, whereas, in July-sown crop, the response was limited to 30 kg N ha^{-1}. Among the herbicide treatments, the mixture that proved very promising in both sowing dates was that of fluridone plus diuron at 0.4 + 0.4 and 0.8 + 0.8 kg a.i. ha^{-1}. However, high rate of norflurazon plus diuron (0.[illegible] 0.8 kg a.i. ha^{-1}) was effective only in July-sown cotton. The performance of these herbicide mixtures was observed to be better under high nitrogen level (60 kg N ha^{-1}) and was comparable to hoe-weeded control under low level of nitrogen (30 kg N ha^{-1}).

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Appendix 1: Common and chemical names of herbicides mentioned in the text.

Common name	Chemical name
Alachlor	2-chloro-2', 6'-diethyl-N-(methoxymethyl) acetanilide.
Barban	4-chloro-2-butynyl m-chlorocarbanilate
Bensulide	O,O-diisopropyl phosphorodithioate S-ester with N-(2-mercaptoethyl) benzenesulfonamide
Butralin	4-(1,1-dimethylethyl)-N-(1-methylprophy)-2,6-dinitrobenzenamine
Chlorpropham	Isoprophyl m-chlorocarbanilate
Chlorothal	Dimethyl tetrachloro terephthalate
Dinitramine	N^4, N^4-diethyl-α α, α-trifluoro-3,5-dinitrotoluene-2,4-diamine
Diuron	3-(3,4-dichlorophenyl)-1,1-dimethyl-urea
Fluridone	1-methyl-3-phenyl-5-[3-(trifluoro-methyl) phenyl] -4(1H)-pyridinone
Fluometuron	1,1-dimethyl-3-(α, α, α-trifluoro-m-tolyl) urea
Glyphosate	N-(phosphonomethyl) glycine
MSMA	Monosodium methanearsonate
MCPA	[(4-chloro-o-tolyl) oxy] acetic acid
Monuron	3-(p-chlorophenyl)-1,1-dimethylurea
Nephtha oil (Naptalam)	N-1-naphthylphthalamic acid
Nitralin	4-(methylsulfonyl)-2, 6-dinitro-N, N-dipropylaniline

Appendix 1 (Continued)

Common name	Chemical name
Noruron	3-(hexahydro-4,7-methanoindan-5-yl)-1, 1-dimethyl urea
Norflurazon	4-chloro-5-(methyl-amino)-2-(α, α, α-trifluoro-m-tolyl)-3-(2H)-pyridazinone
Oxadiazon	2-tert-butyl-4-(2,4-dichloro-5-isopropoxyphenyl)- Δ^2 -1,3,4-oxadiazoline-5-one
Paraquat	1,1'-dimethyl-4,4'-bipyridinium ion
Prometryne	2,4-bis(isopropylamino)-6-(methylthio)-s-triazine
Tetrafluron	N,N-dimethyl-N'-[3-(1,1,2,2-tretrafluoroethoxy) phenyl] urea
Trifluralin	α, α, α-trifluoro-2,6-dinitro-N,N-diprophyl-p-toluidine

Appendix 2: Analysis of variance of seed cotton yield (kg) in weed competition study, Samaru, 1981.

Source of variation	DF	SS	MS	F
Replications	3	5.9	2.0	-
Main-plot (Sowing dates)	1	39.7	39.7	99.3*
Error (A)	3	1.3	0.4	-
Sub-plot(Weed compeition duration)	11	130.0	11.8	9.1*
Main-plot x Sub-plot	11	24.0	2.2	1.7^{NS}
Error (B)	66	84.2	1.3	-
Total	95			

* = Significant differences at 5% level

NS = No significant differences.

Appendix 3: Analysis of variance of weed dry matter (kg) in weed competition study, Samaru, 1981.

Source of variation	DF	SS	MS	F
Replications	3	7.8	2.6	-
Main-plot (Sowing dates)	1	11.2	11.2	4.9*
Error (A)	3	7.0	2.3	-
Sub-plot(Weed competition duration)	11	185.6	16.9	13.0*
Main-plot x Sub-plot	11	39.7	3.6	2.8*
Error (B)	66	85.0	1.3	-
Total	95			

* = Significant differences at 5% level.

Appendix 4\ Analysis of variance of seed cotton yield (kg) in the weed control study, Samaru, 1981.

Source of variation	DF	SS	MS	F
Replications	3	323.0	107.7	-
Nitrogen levels (N)	2	2,732.4	1,366.2	13.9*
Sowing dates (D)	1	420.9	420.9	4.3^{NS}
N x D	2	566.4	283.2	2.9^{NS}
Error (A)	15	1,475.0	98.3	-
Weed control treatment (W)	5	12,567.7	2,513.5	48.7*
N x W	10	872.7	87.3	1.7^{NS}
D x W	5	597.7	119.5	2.3*
N x D x W	10	213.8	21.4	0.4^{NS}
Error (B)	90	4,648.5	51.6	-
Total	143			

* = Significant differences at 5% level

NS = No significant differences.

Appendix 5: Analysis of variance of weed dry matter (kg) in the weed control study, Samaru, 1981.

Source of variation	DF	SS	MS	F
Replications	3	2.6	0.9	-
Nitrogen levels (N)	2	3.1	1.5	4.0*
Sowing dates (D)	1	1.9	1.9	5.0*
N x D	2	0.9	0.5	1.3*
Error (A)	1	5.6	0.4	-
Weed control treatment (W)	5	110.3	22.1	110.5*
N x W	10	3.5	0.3	1.5*
D x W	5	1.1	0.2	1.0^{NS}
N x D x W	10	8.5	0.8	4.0*
Error (B)	90	14.5	0.2	-
Total	143			

* = Significant differences at 5% level

NS = No significant differences.