RESPONSE OF GARLIC (*Allium sativum* L.) TO LEVELS OF NITROGEN, PHOSPHORUS AND IRRIGATION INTERVAL

BY

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A dissertation submitted to the Postgraduate School, Ahmadu Bello University in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy in Irrigation Agronomy.

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MAY, 1999

DECLARATION

I hereby declare the dissertation entitled "Response of garlic (Allium sativum L.) to levels of nitrogen, phosphorous and irrigation interval" contained the record of my own research and is written by me. It has not been previously presented in any form for the award of any degree.

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CERTIFICATION

The dissertation entitled "Response of garlic (Allium sativum L.) to levels of nitrogen, phosphorus and irrigation interval" by Sani Miko meets the regulations governing the award of the degree of Doctor of Philosophy of the Ahmadu Bello University, Zaria, and that it is approved for its immense contribution to scientific knowledge and literary presentation.

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DEDICATION

The dissertation has been dedicated to the numerous garlic growers in Kano and Sokoto States Nigeria, who never relented their efforts to produce this important crop, despite its being relegated to the background in all our past research efforts in the country.

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ABSTRACT

Field experiments to study the response of garlic (Allium sativum L.) crop to varying levels of nitrogen, phosphorus and irrigation interval were conducted during the 1994/95, 1995/96 and 1996/97 dry seasons (November to March) at the Institute for Agricultural Research, Irrigation farm, Samaru, Zaria (11° 11'N;07° 38'E 686m above sea level). The treatments consisted of four nitrogen levels (0, 75, 150 and 225KgN/ha), three levels of phosphorus (0,75, and 150Kg$P_2 0_5$/ha) and three irrigation intervals (5,10 and 15 days between irrigations). The experiments were conducted in a split-plot design with nitrogen levels and irrigation intervals forming the main treatments while the phosphorus levels were assigned to the sub-plots. The treatments were replicated three times in each season.

Results obtained indicated that the application of 75KgN/ha produced significant increases in all growth and yield characters compared with control and higher rate of applied nitrogen had no further influence on these characters. Plots that received no nitrogen, however, produced significantly shorter plants, lower leaf number/plant, dry matter/plant and all yield components compared with the application of 75KgN/ha. Bulb yield and bulb phosphorus content were observed to increase significantly with increase in applied N only up to 75KgN/ha. The bulb crude protein content, however, was found to progressively and significantly increase with increasing rate of nitrogen up to 225KgN/ha.

Increasing the level of phosphorus from 0 to 75Kg$P_2 0_5$/ha significantly increased plant height, dry matter/plant, number of leaves/plant, CGR and RGR in all the 3 experiments. Similarly, all other yield components responded significantly to applied phosphorus only upto 75Kg$P_2 0_5$/ha. Further, increase in applied phosphorus beyond 75Kg$P_2 0_5$/ha did not produce any appreciable increase. Similar trend was recorded on cured bulb yield/ha. The bulb phosphorus and protein contents also registered significant response to applied phosphorus only upto 75kgN/ha.

Growth and yield characters as well as bulb yield, bulb phosphorus and crude protein contents were significantly decreased with increase in the number of days between irrigations but only upto 10-day irrigation interval, while further delay in irrigation to 15days between irrigations did not affect these characters appreciably. Generally, the 5-day irrigation interval significantly out yielded 10 and 15-day interval on all parameters assessed.

Correlation analysis showed positive and significant associations between bulb yield and all characters assessed in all seasons, except in 1995/96 where insignificant associations were registered between bulb yield and average number of leaves/plant; a negative non-significant correlations between bulb yield and average clove weight. Dry matter/plant and average bulb weight had the highest direct individual contributions to bulb yield, while combinations of plant height and drymatter/plant (1995/96 trial) as well as bulb weight and bulb size (1994/96) were the highest contributors to bulb yield. Polynomial response of bulb yield to

nitrogen, phosphorus and irrigation interval indicated quadratic curve to have a better fit to the observed yields throughout the seasons.

CONTENTS

		Page
Title		i
Declaration		ii
Certification		iii
Dedication		iv
Acknowledgement		v
Abstract		viii
Table of contents		xi
List of tables		xv
List of figures		xx
List of Appendices		xxi
1.0	INTRODUCTION	1
2.0	LITERATURE REVIEW	5
2.1	Effect of Nitrogen on the Growth and Yield of Garlic	5
2.2	Effect of Phosphorus on the Growth and Yield of Garlic	12
2.3	Effect of irrigation on the Growth and Yield of Garlic	15
2.4	Nitrogen and Phosphorus interaction on Growth and Yield of garlic	20
2.5	Nitrogen and irrigation interaction on Growth and Yield of garlic	21
2.6	Phosphorus and irrigation interaction or Growth and Yield of garlic	22
2.7	Simple correlation and Path-coefficient studies in garlic	23
3.0	MATERIALS AND METHODS	26
3.1	Experimental Site	26

3.2	Treatments and Experimental design	26
3.3	Soil Sample Analysis	27
3.3.1	Soil Textural Class	27
3.3.2	Soil pH and Organic Carbon	28
3.3.3	Total Residual Nitrogen	28
3.3.4	Available Phosphorus	28
3.3.5	Exchangeable Cateons	28
3.4	Cultural Practices	28
3.4.1	Land Preparation	28
3.4.2	Planting material, sowing and irrigation	29
3.4.3	Fertilizer application	29
3.4.4	Weed control	30
3.4.5	Pest and Disease control	30
3.4.6	Harvesting and bulb curing	30
3.5	Data Collection	30
3.5.1	Plant height	30
3.5.2	Number of leaves per plant	31
3.5.3	Dry matter production per plant	31
3.5.4	Crop growth rate	31
3.5.5	Relative growth rate	31
3.5.6	Mean number of days to maturity	32
3.5.7	Mean number of cloves per bulb	32
3.5.8	Mean clove weight	32
3.5.9	Mean bulb weight	32
3.5.10	Mean bulb size	32
3.5.11	Fresh bulb yield per hectare	32

.5.12	Cured bulb yield per hectare	33
.5.13	Bulb crude protein content	33
.5.14	Bulb phosphorus content	33
.6.	Statistical Analysis of date.	34
.0	**RESULTS**	35
.1.0	Effect of nitrogen, phosphorus and Irrigation interval on growth of garlic	35
.1.1	Plant height	35
.1.2	Mean number of leaves per plant, ...	51
.1.3	Dry matter production per plant, ...	62
.1.4	Crop growth rate, ...	78
.1.5	Relative growth rate, ...	84
.1.6	Mean number of days to maturity, ...	90
.2.	Effect of nitrogen, phosphorus and Irrigation interval on yield components and yield of garlic .	97
.2.1	Mean number of cloves per bulb, ...	97
.2.2	Mean clove weight, ...	103
.2.3	Mean bulb size, ...	106
.2.4	Mean bulb weight, ...	109
.2.5	Fresh bulb yield per hectare, ...	113
.2.6	Cured bulb yield per hectare, ...	118
.2.7	Bulb crude protein content, ...	125
.2.8	Bulb phosphorus content, ...	132
.3.	Simple correlation studies	140
.3.1	Path coefficient analysis	147

4.3.2 Polynomial Response of bulb yield to nitrogen, phosphorus and irrigation interval 173

5.0 DISCUSSION 178

5.1 Effect of Nitrogen 179

5.2 Effect of Phoshorus 183

5.3 Effect of Irrigation interval 185

5.4 Nitrogen x phosphorus 189

5.5 Nitrogen x Irrigation interval 192

5.6 Phosphorus x Irrigation interval 196

5.7 Simple correlation studies and path-coefficient studies 197

5.8 Polynomial response 199

6.0 **SUMMARY AND CONCLUSION** 200

REFERENCES 203

APPENDICES 212

BIOGRAPHY 219

LIST OF TABLES

Table Page

1. Plant height (cm) of garlic as influenced by rates of Nitrogen, phosphorus and irrigation interval in 1994/95.... 37

2. Interaction between nitrogen and phosphourus, as well as nitroge x irrigation interval on plant height at 12 and 6 WAS in 1994/95 dry season at Samaru..... 39

3. Plant height (cm) of garlic as affected by rate of nitrogen, phosphorus and irrigation interval in 1995/96 dry season at Samaru..... 41

4. Nigrogen x irrigation interval on plant height at 6 WAS during 1995/96 season at samaru..... 43

5. Plant height (cm) of garlic as affected by rates of nitrogen, phosphorus and irrigation interval during 1996/97 dry season at Samaru..... 45

6. Nigrogen x phosphorus and Nitrogen x irrigation interval on plant height (cm) at 6, 15; 6 and 9 WAS, respectively in 1996/97 dry season at Samaru 47

7. Phoshorus x irrigation interval interaction on Plant height (cm) at 6 WAS during 1996/97 season at Samaru 49

8. Average number of leaves/plant as affected by rates of nitrogen, phosphorus and irrigation interval during 1994/95 season at Samaru 53

9. Average number of leaves/plant as affected by rates of nitrogen, phosphorus and irrigation interval in 1995/96 season at Samaru 56

10. Average number of leaves/plant as affected by rates of nitrogen, phosphorus and irrigation interval in 1996/97 season at Samaru..... 59

11. Nitrogen x phosphorus (at 5 WAS) and Nitrogen x irrigation interval (at 12 WAS) on average number of leaves/plant in 1996/97 trial at Samaru 61

12. Dry matter production (g/plant) as affected by rates of nitrogen, phosphorus and irrigation interval in 1994/95 season at Samaru 64

13. Interaction between nitrogen and phosphorus (at 15 WAS) as well as nitrogen and irrigation interval (at 9 and 12 WAS) on dry matter production (g/plant) during 1994/95 trial at Samaru 66

14. Dry matter production (g/plant) as influenced by rates of nitrogen, phosphorus and irrigation interval druing 1995/96 season at Samaru..... 68

15. Nitrogen x irrigation interval interaction on dry matter production (g/plant) at i and 12 WAS in 1995/96 season at Samaru..... 70

16. Dry matter production (g/plant) as affected by rates of nitrogen, phosphorus and irrigation interval during 1996/97 season at Samaru 73

17. Nitrogen x irrigation interval (at 9 and 12 WAS) and phosphorus x irrigation interval (at 12 WAS) on dry matter production (g/plant) during 1996/97 season at Samaru..... 75

18. Crop growth rate (g/dm^2/wk) as affected by rates of nitrogen phosphorus and irrigation interval during 1994/95 season at Samaru..... 79

19. Crop growth rate (g/dm^2/wk) as influenced by rates of nitrogen phosphorus and irrigation interval during 1995/96 season at Samaru..... 81

20. Crop growth rate (g/dm^2/wk) as affected by rates of nitrogen phosphorus and irrigation interval during 1996/97 dry season at Samaru 83

21. Relative growth rate (g/g/wk) as affected by rates of nitrogen phosphorus and irrigation interval during 1994/95 dry season at Samaru 85

22. Relative growth rate (g/g/wk) as affected by rates of nitrogen phosphorus and irrigation interval during 1995/96 dry season at Samaru 87

23. Relative growth rate (g/g/wk) as affected by rates of nitrogen phosphorus and irrigation interval during 1996/97 dry season at Samaru 89

24. Number of days to maturity as affected by varying levels of nitrogen, phosphorus and irrigation interval during 1994/95, 1995/96 and 1996/97 dry seasons as well as in the combined analysis at Samaru..... 92

25. Nitrogen x phosphorus (combined), nitrogen x irrigation interval (1994/95, 1996/97 and in combined analysis) and phosphorus x irrigation interval (combined) on number of days to maturity at Samaru..... 94

26. Number of days to maturity of garlic as affected by phosphorus x irrigation interval in the combined analysis ..94

27. Number of cloves/bulb as affected by varying levels of nitrogen, phosphorus and irrigation interval during 1994/95, 1995/96, 1996/997 dry seasons and in combined analysis at Samaru.....98

28. Nitrogen x phosphorus and nitrogen x irrigation interval on number of cloves/bulb in the combined analysis and in 1994/95 season at Samaru 100

29. Mean clove weight (gm) as affected by varying levels of nitrogen, phosphorus and irrigation interval during 1994/95, 1995/96, 1996/97 dry seasons as well as in the combined analysis at Samaru..... 104

30. Mean bulb size (cm) as influenced by varying levels of nitrogen, phosphorus and irrigation interval during 1994/95, 1995/96 and 1996/97 dry seasons as well as in the combined analysis at Samaru 107

31. Mean bulb weight (gm) as affected by varying levels of nitrogen, phosphorus and irrigation interval during 1994/95, 1995/96 and 1996/97 dry seasons as well as in the combined analysis at Samaru 110

32. Nitrogen x phosphorus (1996/97 and combined) and nitrogen x irrigation interval (1994/95, 1996/97 and combined) on average bulb weight at Samaru. 112

33. Fresh bulb yield (Kg/ha) as influenced by varying levels of nitrogen, phosphorus and irrigation interval during 1994/95, 1995/96 and 1996/97 dry seasons as well as in the combined analysis at Samaru 115

34. Nitrogen x phosphorus (1994/95 and combined), and nitrogen x irrigation interval (1994/95, 1996/97 and combined) on fresh bulb yield (Kg/ha) at Samaru 117

35. Cured bulb yield (Kg/ha) as influenced by varying levels of nitrogen, phosphorus and irrigation interval during 1994/95, 1995/96 and 1996/97 dry seasons as well as in the combined analysis at Samaru 120

36. Nitrogen x phosphorus on cured bulb yield (Kg/ha) during 1995/96, 1996/97 dry seasons and in the combined analysis at Samaru 122

37. Nitrogen x irrigation interval on cured bulb yield (Kg/ha) during 1994/95, 1995/96 and 1996/97 dry seasons as well as in the combined analysis 123

38. Bulb crude protein content (g/100g sample) as influenced by varying levels of nitrogen, phosphorus and irrigation interval during 1994/95, 1995/96 and 1996/97 dry seasons as well as in combined analysis at Samaru 126

39. Nitrogen x phosphorus on bulb crude protein content (g/100g sample) during 1995/96 and 1996/97 dry seasons as well as in the combined analysis 128

40. Nitrogen x irrigation interval on crude protein content (g/100g sample) during 1994/95, 1995/96 and 1996/97 dry seasons as well as in the combined analysis..... 130

41. Phosphorus x irrigation interval on bulb crude protein content (g/100g sample) during 1994/95, 1995/96 and 1996/97 dry seasons as well as in the combined analysis 131

42. Bulb phosphrus content (g/100g sample) as affected by varying levels of nitrogen, phosphorus and irrigation interval during 1994/95, 1995/96 and 1996/97 dry seasons as well as in the combined analysis at Samaru..... 134

43. Nitrogen x phosphorus on bulb phosphorus content (g/100g sample) during 1995/96 and 1996/97 dry seasons as well as in the combined analysis 136

44. Nitrogen x irrigation interval on bulb phosphorus content (g/100g sample) in the combined analysis 138

45. Phosphorus x irrigation interval on bulb phosphorus content (g/100g sample) during 1994/95, 1995.96 and 1996/97 dry seasons as well as in the combined analysis 139

46. Matrix of correlation coefficient between cured bulb yield (Kg/ha) and some growth and yield components in 1994/95 season at Samaru 144

47. Matrix of correlation coefficients between cured bulb yield (Kg/ha) and some growth and yield components in 1995/96 dry season at Samaru 145

48. Matrix of correlation coefficients between cured bulb yield (Kg/ha) and some growth and yield components in 1996/97 dry season at Samaru 146

. The direct and indirect effects of some growth characters to bulb yield in 1994/95 season at Samaru 149

. The direct and indirect effects of some growth characters to cured bulb yield in 1995/96 dry season at Samaru 149

. The direct and indirect effects of some growth characters to cured bulb yield in 1996/97 dry season at Samaru. 151

. Percentage contribution of different growht characters to bulb yield in 1994/95 dry season at Samaru 157

. Percentage contributions of different growth characters to cured bulb yield in 1995/96 dry season at Samaru 158

. Percentage contributions of some growth characters to cured bulb yield in 1996/97 dry season at Samaru 159

. The direct and indirect effects of some yield components to bulb yield in 1994/95 dry season at Samaru.....161

. The direct and indirect effects of some yield components to cured bulb yield in 1995/96 dry season at Samaru 161

. The direct and indirct effects of different yield compnents to cured bulb yield in 1996/97 dry season at Samaru 162

. Percentage contribution of different yield components to bulb yield in 1994/95 dry season at Samaru 169

. Percentage contributions of different yield components to cured bulb yield in 1995/96 dry season at Samaru..... 170

. Percentage contributions of different yield components to cured bulb yield in 1996/97 dry season at Samaru. 171

. Polynomial response of bulb yield (kg/ha) to applied nitrogen, phosphorus and irrigation interval during 1994/95 dry season at Samaru..... 174

. Polynomial response of bulb yield (kg/ha) to applied nitrogen, phosphorus and irrigation interval during 1995/96 dry season at Samaru..... 175

. Polynomial response of bulb yield (kg/ha) to applied nitrogen, phosphorus and irrigation interval during 1996/97 dry season at Samaru. 176

FIGURES

Figure Page

1. Path-diagram showing inter-relations of cured bulb yield (Kg/ha) and some growth parameters in 1994/95 dry season at Samaru 153

ii. Path-diagram showing inter-relations of cured bulb yield (Kg/ha) and some growth parameters in 1995/96 dry season at Samaru 154

iii. Path-diagram showing inter-relations between cured bulb yield (Kg/ha) and some growth characters in 1996/97 dry season at Samaru 155

iv. Path-diagram showing inter-relations of cured bulb yield (Kg/ha) and some yield components in 1994/95 dry season at Samaru 164

v. Path-diagram showing inter-relations of cured bulb yield (Kg/ha) and some yield components in 1995/96 dry season at Samaru 165

vi. Path-diagram showing inter-relations of cured bulb yield and some yield components in 1996/97 dry season at Samaru ...166

LIST OF APPENDICES

Appendix		Page
i.	Meteorological data showing minimum and maximum temperatures, relative humidity and sunshine hours in Samaru during 1994/95 dry season.....	212
ii.	Meteorological data showing minimum and maximum temperatures, relative humidity and sunshine hours in Samaru during 1995/96 dry season.....	213
iii.	Meteorological data showing minimum and maximum temperatures, relative humidity and sunshine hours in Samaru during 1996/97 dry season.	214
iv.	Physico-chemical properties of the soils of the experimental sites during the 1994/95, 1995/96 and 1996/97 dry seasons at Samaru.....	215
v.	Polynomial response of bulb yield to applied nitrogen, phosphorus and irrigation interval in 1994/95 dry season at Samaru.....	216
vi.	Polynomial response of bulb yield to applied nitrogen, phosphorus and irrigation interval in 1995/96 dry season at Samaru.....	216
vii.	Polynomial response of bulb yield to applied nitrogen, phosphorus and irrigation interval in 1996/97 dry season at Samaru.....	217
viii.	Composition of composite sample of garlic bulbs from the 3 seasons Experiment.....	218

CHAPTER ONE

1.0 INTRODUCTION

Garlic (Allium sativum L.) belongs to the family Alliaceae. Other members of the Alliaceae family include onion (Allium cepa L.), shallot (Allium ascalonicum L.) and chive (Allium schoenoprasum L.). Garlic plant, when fully grown, is about 40 to 60cm tall from the ground surface to the tip of the longest leaf. The crop consists of an underground bulb and the above-ground vegetative parts. The only vegetative part of garlic consists of the leaves, which are flat and slender. The inflorescence of the crop is composed of numberous flowers, that may either be white or pink in colour, while the peduncle is of variable length depending on cultivar. The rooting systems is fibrous. The bulb comprises of small bulbils called cloves, which are the propagating materials of the crop (Purseglove, 1972).

Garlic was believed to have originated in central Asia and later spread to the mediterranean region where it is mostly grown and highly valued as reported by Tindal (1986). The crop was later carried to the western world probably by the Spanish, French and Portuguese explorers.

Garlic, being a minor crop, is usually categorized along with other horticultural crops, though no clear picture of world production is available. However, Mexico appears to be among the leading world producers of garlic. It was reported by Purseglove, (1972) and Tindal (1986) that Spain leads the world in garlic production followed by Egypt. Other major producing countries include Bulgaria, Romania, Poland, France

and Japan. In Nigeria, there is limited production which is mainly confined to the Northern Guinea and the Sudan Savanna ecological zones. The crop is mainly grown during dry season under irrigation in parts of Borno, Sokoto, Kebbi, Katsina, and Kano states. However, there is no available literature on garlic production and trade in Nigeria.

Garlic crop requires cool but dry weather conditions for proper growth. However, high humidity and excessive moisture are highly detrimental to the growth and development of the crop, as high moisture results in rotting of roots and protective bulb scale leaves. Jones and Mann (1963) reported that long days and high temperatures favour bulb development, but garlic grows more vegetatively under short period and cool dry condition.

Although the production of garlic in Nigeria is limited both in quantity and land area, its importance, mainly in traditional medicine and as a condiment, has made it an economically important vegetable crop. Garlic bulb contains 62.8% moisture, 6.3% protein, 29.0% carbohydrate, 0.1 fat, 1.0%minerals, 0.8% fibre, 0.03% calcium, 0.6% phosphorus and 0.13% vitamins. It also contains pungent sulphur compounds (Purseglove, 1972). The crop has several uses as food or medicine and is used in the preservation of meat and meat products. The green parts as well as the bulbs are used as spices in salad and seasoning of vegetables. Garlic preparations could be used to effectively cure whooping cough, lung diseases, stomach pains and childbirth disorders. Extract

from garlic is used as a curative against ear ache and eye sores. Garlic could be used as an antidote against some poisons and also as antibacterial as reported by Debkitaniya et al., (1981). The garlic extract could also be used as an insecticide, while Purseglove (1972) reported that the level of cholesterol in human blood could be reduced by garlic extract. The volatile sulphur oils (Idiallyl, thiosulphinate and allicin) extracted from garlic bulbs could be used to treat several skin infections. Garlic is also generally repulsive to snakes.

Judicious and adequate fertilization are pre-requisite to successful garlic production. The soils in the garlic producing areas of Nigeria have been observed to be very low in residual nitrogen, which is one of the elements consumed in large quantities by the crop, while phosphorus is relatively more abundant in the soils. Nitrogen is also highly mobile in the soil and therefore, can be lost through leaching or volatilization. Phosphorus is not mobile in the soil, thus the two elements (N and P), have to be judiciously applied to the crop as over-fertilization leads to waste of inputs and also enhances vegetative growth at the expense of reproductive phase. Another limiting factor to garlic production is water. As it was earlier stated, the crop is normally grown during the dry season and irrigation water could be a limiting factor. In addition, garlic has a fibrous and limited root system, and therefore, most of its roots are found within the

first 25cm of the soil profile. As such, the roots do not go deep enough in search of moisture, consequently the crop requires efficient irrigation scheduling in order to avoid exposing the crop to water stress, which could lead to significant yield reduction as reported by Sula (1989). On the other hand, too frequent irrigation could lead to either leaching of nutrients or where adequate drainage is lacking, this may lead to rise in soil water table, which could limit the potential productivity of both the land and the crop. It becomes imperative, therefore, to determine the most suitable irrigation schedule for the crop. Garlic crop has also been neglected in terms of research in this country.

It is in view of the above background that this project was undertaken with the following objectives:

(a) To determine the optimum nitrogen and phosphorus levels for optimum bulb yield in garlic

(b) To determine the most efficient irrigation schedule for garlic production.

(c) To study any interactions between N,P and irrigation interval on yield and yield parameters of the crop.

CHAPTER TWO

.0 LITERATURE REVIEW

.1 Effect of Nitrogen on the Growth and Yield of Garlic

Nitrogen, generally, has its most profound influence on the vegetative development of crops. When supplied in adequate quantity nitrogen ensures a healthy plant growth, which is manifested by the increased vigour, size and the deeper green colour of the foliage. The effect of nitrogen on the general vigour of crops is as a result of its positive effects on cell division, cell elongation, cell expansion, synthesis of amino acids, enzymes and chlorophyll. Unfortunately, most tropical soils are deficient or low in residual nitrogen. Consequently several workers have recorded positive responses by most crops (including garlic) to nitrogen application.

Nehra et. al., (1988) working on onions, reported that nitrogen fertilization had profound influence on the assimilatory leaf area of onion and further stated that application of 40 and 80 Kg N/ha which were statistically at par on all parameters except leaves/plant, significantly increased plant height. The application of 80Kg N/ha however, produced statistically more leaves per plant than 40Kg N/ha. Similar reports on garlic were recorded by Borabash and Kochina (1987), who noted that mineral fertilizing increased the assimilatory leaf area, photosynthetic productivity and yields of garlic. In

India, Singh et. al., (1984) reported that the plant height of garlic was significantly increased with increasing rates of nitrogen only upto 100kg N/ha beyond which general growth of the crop was significantly decreased. Likewise, Lachica (1982), Buwalda (1986) and Maksoud et. al., (1984) all recorded significant increase in garlic plant height, number of leaves per plant and dry matter production with the application of nitrogen ranging from 30 to 80kgN/ha. Kremer et. al., (1979) however working with different rates of nitrogen (0, 90, 180, 220 and 300kg N/ha) on onion reported that the application of 180kg N/ha produced statistically highest drymatter per plant than any other rate. El-Tabbakh et. al., (1979) on the other hand reported that increasing nitrogen rate up to 120kg N/ha increased onion plant dimensions, dry matter per plant and plant height. It was also reported by Ismail et al (1979) that increased application of nitrogen to onion upto 192kg N/ha produced significant increase on the average number of leaves per plant and plant height. Other workers who reported positive effects of nitrogen on growth and development of onion include Caraballo et. al., (1989), Islam and Haque (1977), Chakrabarti et. al., (1980), Khomenko and Lysyuk (1981), Jitendra and Dhankar (1989) and Khan et. al., (1977). Aliudin (1978) working with garlic however, reported that the application of 180 and 240kg N/ha

produced statistically similar plant heights, leaf number per plant and plant dry weight. Similarly Henriksen (1978) recorded the highest garlic response to nitrogen application at 150kg N/ha, which produced statistically taller plants and more plant dry matter. The garlic relative growth rate was reported by Buwald and Freeman (1987) to have been affected positively by the application of nitrogen. Singh (1978) and Henriksen (1987) independently reported that application of nitrogen at 120kg N/ha increased the length of maturity of onion, leaf number per plant and crop growth rate. Similarly, Babaji (1996) reported significant increase in plant height, number of leaves/plant, leaf dry and fresh weights of garlic with the application of 40kg N/ha .

The yield and yield components of garlic have been reported by many scientists to be affected positively by the application of nitrogen. Escaff and Aljaro (1982) recorded significant increase in garlic bulb yield with the application of 150kgN/ha. Maksoud et. al., (1984) on the other hand observed the most significant positive effect of applied N on average bulb weight, bulb diameter and final bulb yield with the application of 360kg N/ha. Aliudin (1978) recorded significant increases in average bulb weight, bulb diameter and average clove weight of garlic when nitrogen rate was increased from 0 to 90kg N/ha, and recorded no statistical difference between 90,

180 and 240kg N/ha on these parameters. Hilman and Noordiyati (1988) on the other hand, reported that the equilibrium N at several levels did not significantly affect bulb diameter, bulb length, number of cloves per bulb and bulb weight of garlic. They, however, noted that the various N treatments registered significant effects on bulb fresh and dry weights, with maximum response attained at 46kg N/ha. Bertoni et. al., (1992) working with garlic in France, reported that depriving the crop of nitrogen at the beginning of bulb growth, accelerated and increased the redistribution of organic nitrogen from leaves and roots to the bulbs. They noted that bulb weight was least affected, though N application increased garlic bulb growth and quality until the beginning of senescence.

Bulb yield and quality of members of the Alliaeceae family have been reported by several workers to be affected positively by the application of nitrogenous fertilizers. Khan et al., (1977) recorded the highest bulb yield in onion with the application of 15 tons/ha of FYM in addition to 50kg N/ha from mineral fertilizers. Reddy and Madalageri (1978), however, obtained the best onion yield with the application of 100kg N/ha, while Singh (1978) reported 112.5kg N/ha to be optimum for highest onion yields. Escaff and Aljaro (1982) recorded 150kg N/ha as the optimum for higher garlic bulb yield,

of best quality and longer shelf life. They however, did not record any significant difference between 150kg N/ha and 225kg N/ha with respect to garlic bulb yield and quality. Minard (1978) however, obtained the best yield response of garlic to nitrogen applied at 210kg N/ha. Haggag et al., (1986) and Khomenko and Lysynk (1981) independently recorded 120kg N/ha as the optimum nitrogen rate for higher bulb yield and quality in onion, while Chakrabarti et. al., (1980) recorded no significant difference between 90 and 120kg N/ha in relation to onion bulb yield. In a related crop, leeks, Kolota (1979) noted that the highest bulb yields were obtained with the application of 200kg N/ha and attributed this to the positive effects of nitrogen on bulb weight and bulb size, which all have direct bearings on the final bulb yield. Lazzari et.al., (1978) and Hedge (1986) all reported significant increase in garlic bulb yield when nitrogen was increased from 0 to 150kg N/ha and attributed this response to the positive effects of nitrogen on dry matter production, bulb weight and average clove number per bulb. Bottcher et al (1979) working with onion reported that increasing nitrogen rates to 200kg N/ha had no unfavourable effect on bulb quality in storage, reduced bulb rotting and shrinkage while it increased marketable bulb yield significantly. Agrawal et. al., (1981) on the other hand recorded 80kg

N/ha to have produced comparable bulb yield to the application of 160kg N/ha. Hou (1980) recorded significant positive effect of applied nitrogen on leeks to bulb protein content; he noted that nitrogen application to leeks significantly lowered the cellulose and lignin contents of leaves and bulbs. Dhian and Sharma (1991) conducted field trials on nitrogen and irrigation regimes on onions and reported that the bulb diameter, bulb dry weight and final bulb yield were significantly increased with increasing nitrogen application only up to 80kg N/ha, while further increase to 120kgN/ha produced no appreciable increase. Palled et. al., (1988) reported that application of 100kg N/ha produced 26.4% higher yields than 75 and 50kg N/ha, respectively, while Islam and Haque (1977) recorded 60Kg N/ha as optimum for higher yields. Maercke and Vereecke (1979) on the other hand reported nitrogen to have no significant effect on bulb diameter, bulb weight and bulb yield and quality of leek crop. They attributed lack of response however, to abnormal weather conditions. Laughlin (1989) working with onion on different rates of nitrogen (0,50, 100 and 200kg N/ha) also reported that the N-fertilizer had no effect on either yield or quality of the bulbs. Jitendra and Dhankar (1989) from India, however, reported that high levels of nitrogen reduced bolting in onion but increased the general vigour and

bulb yield, and recorded the highest bulb yield with the application of 160kg N/ha. Thenabadui et. al., (1975) working on a related crop, shallot, recorded significant yield response to applied nitrogen upto 75kg N/ha. Omar and Arafa (1982) reported that the highest garlic bulb yield and bulb diameter were obtained when applied nitrogen was increased from 75 to 225kg N/ha. Ruiz (1985) from Chile also reported that increasing rates of applied nitrogen from 0 to 150kg N/ha significantly increased garlic bulb yield from 4.6 to 10.6tons/ha. However, increase of nitrogen on garlic bulb quality was obtained only at 225kg N/ha. Olupinyo (1995) testing varying levels of nitrogen on garlic crop reported significant increase in average number of cloves per bulb, average bulb weight, bulb size and final bulb yield only when applied nitrogen rate was raised from 0 to 100kg N/ha, further increase did not register appreciable increase. Similarly Babaji (1996) recorded significant increases in all yield components and final bulb yield of garlic with the application of 40kg N/ha. Bichi (1997) on the other hand, recorded significant increases in bulb weight, number of cloves per bulb, bulb diameter and bulb yield with the application of 75kg N/ha while clove weight responded only at 150kg N/ha, beyond which there was a significant reduction.

2.2 Effect of Phosphorus on the Growth and Yield of Garlic

Phosphorus is one of the 16 essential elements that is vital for plant growth and development. Phosphorus nutrition is very important for effective root development, protein synthesis and energy formation and transfer. However, phosphorus is one of the limiting elements in most tropical agricultural lands. Deficiency of phosphorus is very prevailent in tropical savanna soils that are characterized by low organic matter content as reported by Bache and Roger (1970). Deficiency of phosphorus in garlic is manifested by older leaves showing wilting, tip die-back and mottling of green area. Garlic, being a shallow rooted crop, requires timely but optimum application ofphosphorus in order to enhance effective root development so as to increase root volume and consequently increase root efficiency in water and nutrient uptake. Phosphorus nutrition in garlic and other related crops depends on the rate applied and the time of application. Escaff and Aljaro (1982) recorded no significant effect of phosphorus on the growth and yield of garlic with the application of 94.2kg P_2O_5/ha during bulbing stage, while Aliudin (1978) reported significant increase in root growth, plant height and dry matter production with the application of 70kg P_2O_5/ha. Minard (1978) on the other hand reported 263kg P_2O_5/ha as optimum for increased dry matter production, leaf number per

plant and final bulb yield. He attributed this effect to the influence of phosphorus on root development, which relates to effective nutrient uptake and water absoption. Borabash and Kochina (1987) also recorded significant increase in assimilating leaf area, photosynthetic productivity and final bulb yield with the application of 90kg P_2O_5/ha to garlic crop. Hilman and Noordiyati (1988) however reported that several levels of phosphorus tested on garlic did not significantly affect bulb diameter, bulb length, number of cloves/bulb and bulb weight, but recorded significant increase in bulb dry weight with the application of 150kg/ha of triple superphosphate.

Rhodes (1978) working with onion, another member of Alliaceae family, reported that addition of phosphorus fertilizers to onion resulted in absorption of high concentration of sulphur and therefore concluded that increased sulphur uptake by onion plants resulted from the increased sulphur absorbing powers of roots with enhanced phosphorus status. Sulphur compounds determine bulb quality in onion and garlic crops. Khan et al (1977) as well as Reddy and Madalageri (1978) also recorded 50Kg P_2O_5/ha as optimum for maximum bulb yield in onions. However, Thenabadui et. al., (1975) did not record any significant effect of phosphorus on growth and yield parameters of shallot and attributed this to high content

of residual phosphorus in the soil. Henriksen (1987) and Singh (1978) all reported that supply of phosphorus to onion produced rapid crop growth rate, increased days to maturity and bulb yield and quality. Anez and Tavira (1986) recorded the highest dry matter production and bulb yield in onions with the application of 120kg P_2O_5/ha, while Haggag et. al., (1986) recorded 60kg P_2O_5/ha as optimum for increased bulb size, bulb weight, bulb yield and quality. Laughlin (1989) working with onion on different rates of phosphorus (0,50, 100 and 200kg P_2O_5/ ha) recorded significant increase in plant height, dry weight of plants and bulb yield when applied-P was raised from 0 to 50kg P_2O_5/ha.

Khomenko and Lysyuk (1981) reported that higher phosphorus rate of 120kg P_2O_5/ha produced better results with regards to plant height and rate of maturity in onion crop; while Chakrabarti et. al., (1980) recorded 90kg P_2O_5/ha to have significantly affected crop growth rate, plant height, number of leaves per plant, bulb fresh and dry weights as well as final bulb yield of onion. However, Islam and Haque (1977) using different rates of phosphorus on onion, reported that 60Kg P_2O_5/ha produced the longest leaves, while 35Kg P_2O_5/ha resulted in higher number of leaves and the highest bulb yield. Kolota (1979) recorded the highest bulb yield in Leeks (Allium spp) with the application of 200Kg P_2O_5/ha.

Maercke and Vereecke (1979) on the other hand recorded no significant effect of phosphorus on the yield and quality of leeks, though they attributed this to abnormal weather conditions. Hou (1980) reported that phosphorus application to leeks had little effect on the bulb protein content, but significantly lowered the lignin content of the bulbs. Souma and Iwabuchi (1982) also reported that adequate phosphate fertilization resulted in increased relative growth rate, increased growth of leaves, number of leaves per plant and bulb yield in onion crop. Agrawal et. al., (1981) recorded significantly higher bulb yield in onion with the application of 40kg P_2O_5/ha, than the other levels, while Galbiatti and Castellane (1990) reported 240kg P_2O_5/ha to be optimum for the highest bulb yield in onion.

3 Effect of Irrigation on the Growth and Yield of Garlic

Garlic, like all other members of Alliaceae family, is a shallow rooted crop and therefore, requires greater attention with respect to its water requirement. Adequate moisture needs to be provided from planting through to maturity in order to obtain good crop growth, development and final yield as reported by Choi et al., (1980). They reported that garlic yields were increased by 64 and 84% respectively when 30mm of water were applied at 10-day interval in 1977 and at 5-day interval in 1978. Irrigation throughout growth period was reported by Choi

et. al., (1980) to be most effective for better crop growth rate, but irrigation at bulbing stage was most important for bulbing process. They, however, noted that the garlic does not withstand excess water application. Lazzari et. al., (1978) as well as Carrijo et. al., (1982) also reported a significant yield increase and increased plant biomass with frequent but light irrigation to garlic. However, Sula (1989) observed that garlic crop that was irrigated once a week prolonged the growth period by 10 - 12 days, but increased number of leaves per plant and leaf area, thus increasing photosynthetic activity and consequently increased bulb size, bulb weight, bulb average number of cloves and final bulb yield. Scalopi et. al., (1971) also reported significant increases in average leaf number per plant, dry matter production, bulb size and bulb yield with frequent but light irrigations. Suh (1987) working with radish, cabbage, hot pepper and garlic, reported that adequate moisture regime significantly and positively influenced their growth, yield and quality, and further stated that amount and timing of irrigation of these crops are very critical to their productivity. Similar results were reported by Bravo and Duimovic (1978) on garlic crop.

Effects of irrigation on growth, development and yields of other related crops (Alliaceae family) have

been documented. Leong (1986) working with Shallot in glass house in Malaysia, reported that a daily application of water at 12.5mm gave significantly higher yields compared with the same volume of water given at longer intervals. Dhian and Sharma (1991) conducted field trials in India involving four irrigation regimes on onion (0.75, 1.00, 1.25 and 1.50 IW/CPE) and reported that bulb diameter, bulb dry weight, plant dry weight and bulb yield increased with increasing IW/CPE ratio. Similarly Hou and Jang (1980) reported that frequent irrigation on leeks increased plant size, increased dry matter production and yields, while reducing the cellulose and lignin contents of the bulbs, though bulb protein content was not affected. Chaudhry and Erinne (1984) however, reported that 3-day irrigation interval produced the highest bulb yield and bulb size of onion. They reported that the lowest yield was obtained with 6-day irrigation interval; though the 3 and 6-day intervals increased bolting and decreased shelf life of bulb.

Hassan (1984) reported that 10-day irrigation interval produced taller plants, larger bulb size and higher bulb yield in onion. Shortening the interval to 5-day reduced bolting but increased bulb doubling. However, El-Tabbakh et. al., (1979) reported that the highest bulb yield, single bulb yield, average bulb size and average bulb weights were obtained by irrigating onion every 3

weeks. They recorded significant reduction in these parameters including plant height, by widening the irrigation interval. However, two week irrigation interval produced the highest plant dry matter, tallest plants, higher N-concentration in tissues, higher chlorophyll as well as total carotenoids content of the onion bulbs. Selinger and Hubner (1984) noted that irrigation increased growth and yield components, including yield in onion. They also observed that adequate moisture supply was essential when bulbs were swelling, but later irrigations tended to delay onion ripening. Nassar and Waly (1977) as well as Bottcher et. al., (1979) independently noted that frequent but light irrigation increased all growth and yield parameters of onion and reduced storage losses. Duranti and Barbieri (1986) testing different irrigation frequencies and planting densitites on garlic reported that plant height, dry matter production and number of leaves per plant were increased with frequent irrigation. They also recorded significant increase in bulb weight, bulb size and final bulb yield with frequent irrigation. Donnari et.al., (1978) working in Argentina with a pink garlic variety reported that crops yielded more when grown in a high moisture regime. Klar et.al., (1977) also recorded significantly higher plant dry weight, leaf number per plant and final bulb yields of onion when irrigations

were given at -0.15 bars and that lack of moisture had detrimental effect on the total growth rate of onion. It was also reported by Caraballo et. al., (1989) that fresh bulb weight, dry bulb weight, bulb diameter, bulb yield and all growth parameters were positively affected by adequate supply of moisture to onion crop. However, Teviotdate et.al., (1990) reported that fresh weight of bulbs of onion and content of soluble solids in onion bulb were not affected by irrigation method or volume of water delivered to the crops. Abidin and Karti (1989) using 3, 6, and 9 days irrigation intervals on garlic reported that the 3-day irrigation interval gave the highest increase in fresh weight, dry weight of bulb, bulb diameter, bulb weight and bulb yield.

Chung (1989) working on effect of irrigation on onions reported that applying irrigation at 5-day interval significantly increased the total bulb yield by influencing bulb size, bulb weight and plant dry matter. Also Kolota (1979) reported that frequent but light irrigation on leek crop resulted in 80% increase in total yield, 82% on commercial yield and also improved crop quality. Similar results were recorded by Kamszowski and Umiecka (1985). Lanzoni and Piolanti (1977) reported that optimum irrigation interval of 5-day markedly increased bulb weight, bulb size and bulb yield of onions.

2.4 Nitrogen and Phosphorus interaction on growth and yield of Garlic

Aliudin (1978) recorded significant increase in plant height, dry matter production and crop growth rate in garlic with the application of 180Kg N/ha in combination with 60Kg P_2O_5/ha. All yield components and bulb yield of garlic were significantly increased. Minard (1978) on the other hand recorded the highest garlic bulb yield with the application of 210Kg N/ha and 263kg P_2O_5/ha. He reported that the increase was as a result of favourable effect of both nitrogen and phosphorus on growth and development of the crops. Escaff and Aljaro (1982) recorded significantly higher bulb size, bulb weight and bulb yield in garlic with the application of 150Kg N/ha in combination with 75Kg P_2O_5/ha. Similarly, Hilman and Noordiyati (1988) reported that application of 100kg Urea/ha and 150kg TSP/ha produced the highest bulb size, bulb dry weight and bulb yield in garlic. They also recorded significantly higher bulb diameter, bulb length and average number of cloves per bulb. On the other hand, Borabash and Kochina (1987) reported that the maximum number of leaves per plant, plant height, leaf area and yields of underground bulbs of garlic were obtained with the application of 90Kg each of N and P_2O_5/ha. Chakrabarti et.al., (1980) working on effects of rates of nitrogen and phosphorus on onion reported no significant N x P

interactions on all parameters assessed, while Khomenko and Lysyuk (1981) recorded 120Kg N/ha in combination with 120Kg P_2O_5/ha as optimum with regards to plant height, rate of maturity of crop and final bulb yield of onion. Kolota (1979) recorded the highest onion bulb yield with the application of 200Kg N/ha in combination with 200kg P_2O_5/ha, while Khan et.al., (1977) recorded the best performance of onion with 50Kg N and 50kg P_2O_5/ha.

2.5 Nitrogen and Irrigation Interaction on Growth and Yield of Garlic

Donnari et.al., (1978) reported that garlic grows faster and yields more when the crop is grown in a high moisture regime and receives nitrogen fertilization at the same time. Lazzari et. al., (1978) also reported that application of 150Kg N/ha with frequent irrigation resulted in the production of highest bulb yield and quality in garlic. Hegde (1986) in a two year trial on onion however, reported that the application of 160kg N/ha in combination with irrigation at 0.45 bar gave the largest bulb size, bulb diameter and final bulb yield. Singh et.al., (1987) testing different rates of nitrogen (0, 60, 90 and 120Kg N/ha) under different irrigation frequencies (1,2,3 and 4 irrigations with 500mm at 20-day interval) reported that the highest onion bulb yield was obtained with the highest N and irrigation rates. This was as a result of their positive effects on bulb size,

bulb weight and plant dry matter. Kolota (1979) also reported that frequent but light irrigation of leek crop in combination with 200kg N/ha produced significant effect on the growth and final bulb yield. Bottcher et.al., (1977) also reported that increasing water supply from 30mm to 90mm along with the application of 130Kg N/ha significantly increased growth, yield and yield components of onion without any deleterious effect on bulb quality and shelf life. El-Tabbakh et.al., (1979) using 2,3,4 and 5-week interval along with 0, 20, 40 and 60Kg N/ha on onion, reported that widening irrigation interval with lower or higher rates of nitrogen had a dwarfing effect on plants and reduced neck length. They reported that the highest bulb yield, tallest plants and higher total dry matter contents were obtained by 3-week irrigation interval in combination with 60Kg N/ha.

2.6 Phosphorus and Irrigation Interaction on Growth and Yield of Garlic

Kolota (1979) working with a related crop (leek) reported that frequent but light irrigation in combination with the application of 200kg P_2O_5/ha resulted in 80% increase in total bulb yield due to their effects on root volume, bulb size, bulb weight and plant dry weight. He attributed this effect to adequate dissolution of the phosphate into soil solution, where the P becomes available for root uptake. Galbiatti and Castellane

(1990) reported significant increase on growth and yield parameters of onion as well as bulb yield with the application of 240kg P_2O_5/ha in combination with 5mm of irrigation water per irrigation. They also recorded significant increase in plant height, root and bulb P content with increasing rate of applied P along with ample soil moisture. Similarly, Khomenko and Lysyuk (1981) reported that higher rates of phosphorus upto 120kg P_2O_5/ha along with irrigation at 70 or 80% of soil water capacity gave better results with regards to plant height, dry matter production, leaf number per plant and rate of maturity of crop. However, Nelsen and Safir (1982) concluded that onion continued with phosphorus nutrition even under water stress, thus recording no statistical difference between crops fertilized with phosphorus and little moisture and fertilized crop with ample moisture, consequently confirming the relative drought tolerance of onion.

2.7 Simple correlation and Path-coefficient Studies in Garlic

Simple correlation studies explains the magnitude and nature of association between pairs of variables that are independent of other variables under study, and the matrix of correlation are of great importance in assessing the relationships of characters with bulb yield for selecting those characters that influence final yield in any crop. Path-coefficient analysis on the other hand

measures direct and indirect effect of each yield contributing characters on yield as reported by Wright, (1921). Miko et.al., (1996) reported a significant and positive correlation between bulb yield and bulb weight. They also recorded significant and positive correlation between bulb diameter, number of cloves per bulb and clove weight with bulb yield of garlic. Bichi, (1997) also reported that the magnitude of correlation between cured bulb yield, average clove weight, average bulb dry weight, bulb diameter, number of leaves per plant, plant height and dry matter production were positive and strong; while number of cloves per bulb and cured bulb yield was not significant, though positive. Babaji (1996) also recorded significant and positive relationship between bulb yield, plant height, bulb diameter, bulb dry weight and number of cloves per bulb; while he recorded weak but positive relationships between number of leaves/plant and bulb yield. Babaji (1996) however, registered a negative correlation between number of days to maturity and all growth and yield characters except dry matter per plant and clove weight where the association was strong and positive.

Miko et. al., (1995) and Bichi (1997) all recorded significant direct contribution of bulb size to the final bulb yield in garlic. However, Bichi (1997) recorded the highest indirect contribution of bulb size to bulb yield

via average clove weight. Average number of leaves per plant was reported by Bichi (1997) to have a significantly higher indirect contribution to bulb yield via bulb diameter.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental site:

Three field experiments were conducted during 1994/95, 1995/96 and 1996/97 dry seasons at the irrigation farm of the Institute for Agricultural Research, Samaru (11°11''N, 07°38'E; 686 metres above sea level) in order to study the response of garlic (Allium sativum L.) to varying levels of nitrogen, phosphorus and irrigation frequency. Samaru is located in the Northern Guinea Savanna zone. The period of experimentation was rainless. However, the average monthly minimum and maximum temperatures across the 3 seasons ranged from 11.1 to 23.0°C and 27.0 35.5°C, respectively. The average relative humidity ranged from 11.93 to 76.40%. Appendices I, II and III present the meteorological data at Samaru during the periods of field experimentation. Laboratory analysis of soil samples of experimental fields indicated the soils to be sandy loam with low nitrogen and cation exchange capacity and a pH of 6.55. The detailed physico-chemical properties of the soils are presented in Appendix IV.

3.2. Treatments and experimental design

The treatments consisted of four nitrogen levels (0, 75, 150 and 225Kg N/ha), three rates of phosphorus (0, 75 and 150 Kg P_2O_5/ha; x 0.44 to convert P_2O_5 to P) and three

irrigation intervals (5, 10 and 15-day). The main treatments consisted of nitrogen levels and irrigation intervals, while phosphorus levels were assigned to subplots. The treatments were replicated three times in a split plot design. A local garlic variety, Ex-Kofa was used in these experiments. Ex-Kofa, when fully grown is about 45cm tall. It is of medium maturity (110 - 125 days) depending on prevailing weather condition. It yields an average of 15tons/ha. Bulbs are medium in size and sealed up at the tip. Each bulb consists of cloves ranging from 10 to 40 depending on bulb size. The gross plot size was 1.5 metre wide which accomodated 10 rows and 2 metre length. The net plot (0.9 x 1.4m) consisted of six inner rows of 2 metres length, leaving 3 plants at the end of each row to exclude the border effect.

3 Soil sample analysis

Composite soil samples from 0 to 30cm were taken prior to land preparation and were analysed for their physico-chemical properties.

3.1 Soil textural class

The soil texture of the experimental field was determined using hydrometer method as described by Boyoucos (1951). After estimating soil composition its textural class was determined by soil texture triangle.

Soil pH and organic carbon

The soil pH and organic carbon of the fields were determined using the laboratory standard procedures as described by Black (1965).

Total residual nitrogen

It was determined in the laboratory using the Macro-Kjeldhal procedure as described by Bremmer, (1965) and IITA, (1975).

Available phosphorus

Soil samples were subjected to laboratory analysis to determine the soil available phosphorus using the method described by Trough (1930), while the extractable phosphorus was determined using molybdate blue colour method suggested by Bray and Kurtzs (1945)

Exchangeable cations

The acetic acid method as described by Reith, (1967) was used for exchangeable cations determination. Atomic absorption spectrophotometry was used to estimate the concentrations of calcium, potassium and magnesium using Perkin Elmers Model 403.

Cultural Practices

Land preparation

The experimental plots were properly ploughed and harrowed twice to obtain a fine tilth. A furrow of 75cm in between strip of 1.5m was dug and used as distributory channel. Later, the strips were encircled with

raised bunds, into basins of 2-meter length. Land preparations were carried out in mid-November. Drainage channels were constructed at the tail end of the field.

2 Planting material, sowing and irrigation

Prior to sowing, garlic bulbs were split into the cloves (planting materials), large and viable cloves were selected for better germination, seedling establishment and growth. The cloves were soaked in water over-night in order to remove the scale leaves covering the cotyledon, which enhanced rapid sprouting. The field was pre-irrigated before sowing to provide good clove-soil-water contact. Immediately after the seed preparation and pre-irrigation, cloves were sown by hand at 10cm between stand and 15cm between rows. General irrigation was given at 5-day interval for 4 weeks during which the seedlings got fully extablished. Subsequently, irrigation treatment was imposed. Two weeks before harvest irrigation was stopped to allow for uniform maturity.

.3 Fertilizer application

A basal dose of half the nitrogen rate and full dose of phosphorus (as per treatments) as well as 30kg K_20/ha were applied at sowing. Urea (46%N),muriate of potash (60%K_20) and single superphosphate (18% P_20_5) were used as sources of nitrogen, phosphorus and potassium, respectively. The second dose of nitrogen was applied as side dressing at four weeks after sowing. The fertilizers were incorporated manually using hand hoe.

3.4.4 Weed control

Weeds were properly controlled by hand hoe. Three hoe weedings were carried out in each season.

3.4.5 Diseases and pest control

No incidence of diseases was recorded throughout the period of experimentation in all seasons. However, termites caused some mild damage to roots in 1995/96 season.

3.4.6 Harvesting and bulb curing

Bulbs were harvested when the leaves turned pale green and started falling down. The field was irrigated lighty two days before harvest to soften the soil for easy harvest. Bulbs were dug out carefully using hand hoes. The harvested bulbs were bagged, labelled, weighed (for fresh bulb yield) and tranferred to a curing room. For curing, bulbs were spread in single layer in an open space to allow the excess moisture to evaporate.

3.5. Data Collection

Five plants per sub plot were randomly tagged and were used for all ancillary measurements. In addition, for destructive samples like dry matter production, bulb dry weight, etc at different growth stages, five (5) plants were dug at random for determination of specific parameters.

3.5.1 Plant height (cm)

The plant height was measured from the sampled

plants from the ground level to the tip of the longest leaf at 6,9,12 and 15 weeks after sowing.

.5.2 Number of leaves per plant.

The total leaf number from the tagged plants was counted and averaged out to obtained the average number of leaves per plant at 6,9,12 and 15 WAS..

.5.3 Dry matter production (gm/plant)

Five random plants were dug out carefully and soil completely removed. The fresh weight was obtained and samples were then oven dried at 70°C to a constant weight. Later, average dry matter production per plant was obtained at 6,9,12 and 15 WAS. The data were further used in growth analysis.

.5.4 Crop Growth Rate (CGR)

It is the dry weight increament per unit area per unit time which was computed using data from dry matter production at 6, 9, 12 and 15 weeks after sowing using the following equation as suggested by Dyson and Watson (1971).

$$CGR = \frac{W_2 - W_1}{t_2 - t_1}$$

Where W_1 and W_2 represented dry matter at times t_1 and t_2, respectively.

5.5 Relative Growth Rate (RGR)

The dry weight increament per unit plant dry weight per unit time (RGR) was computed at 9, 12, and 15 weeks after sowing using the following equation given by Dyson and Watson (1971).

$$RGR = \frac{Log_e W_2 - Log_e W_1}{t_2 - t_1}$$

W_1 and W_2 connotes dry matter at times t_1 and t_2, respectively.

.6 Number of days to maturity

Determined by counting the number of days from sowing to maturity indicated by the change of colour from green to pale-green and the leaves had fallen.

.7 Mean number of cloves per bulb.

The five tagged bulbs were split into cloves and counted; the number was divided by five to get the average number of cloves per bulb.

.8 Mean clove weight (gm)

The counted cloves from the above observation were weighed and divided by the total number of cloves to get the mean clove weight.

.9 Mean bulb weight (gm)

Tagged plants were dug out seperately at harvest and weighed. The total weight was averaged to get the mean bulb weight.

.10 Mean bulb size (cm).

The diameter of the five bulbs harvested was determined at their widest girth using a vernier caliper, from which the mean bulb size was obtained.

.11 Fresh Bulb yield per hectare

The bulbs harvested from each net plot were collected, cleaned and weighed. The weights were later expressed in kilograms per hectare.

3.5.12 Cured Bulb yield per hectare

The harvested bulbs from each net plot were cured by sun-drying in a single layer for a period of two weeks. The cured bulbs were weighed and values extrapolated to yield in kg/ha.

3.5.13 Bulb Crude Protein Content

The crude protein content was determined from a sample of each treatment using the Micro-Kjeldhal procedure (A.O.A.C., 1975), The composite bulb sample was oven-dried, ground and sieved. One gram of the sieved sample was digested using sulphuric acid, with copper and sodium sulphates acting as catalysts. The solution was then distilled into boric acid. The distillate was later titrated against a standard hydrochloric acid (HCl) and the percent N content determined from the titre. The crude protein content of the samples was finally obtained by multiplying the percent N content with a factor of 6.25 as reported by Sankaram (1966) and A.O.A.C. (1975).

3.5.14 Mean Phosphorus content of the bulbs

The bulb phosphorus content was determined by the triple acid (H_2S0_4 - $HCLO_3$-HNO_3) wet digestion method. The phosphorus in the digested samples was then estimated by the molybdo-phosphoric yellow colour method as described by Dirk and Myrna (1984).

3.6. Statistical Analysis of Data

All data collected were subjected to analysis of variance as described by Snedecor and Cochran (1967). If significant difference existed the treatment means were evaluated using Duncan Multiple Range Test (Duncan, 1955). Simple correlation analysis was done to ascertain the type and magnitude of relationships between the different variables. A polynomial response of the bulb yield to nitrogen, phosphorus and irrigation intervals were worked out as descrebed by Little and Hills (1978). Regression analysis as described by Steel and Torrie (1984), was also carried out to determine the optimum level of nitrogen for maximum bulb yield. Path co-efficient analysis as reported by Dewey and Lu (1959), was also done to determine the direct and indirect contributions of some important growth and yield components to bulb yield, while the percent contribution of each of the growth and yield components to bulb yield was partitioned as reported by Ajala et.al., (1996).

CHAPTER FOUR

4.0 RESULTS

4.1.0 Effect of nitrogen, phosphorus and irrigation interval on growth of garlic.

4.1.1 Plant height (1994/95)

The mean plant height (cm) sampled at different periods as affected by nitrogen, phosphorus and irrigation freqeuency and significance of interactions during 1994/95 dry season is presented in Table 1.

The results indicated that nitrogen application has influenced plant height at all sampling periods. There was a significant increase in plant height with increase in nitrogen rate only from 0 to 75Kg N/ha at all sampling stages. No significant difference in height was recorded between 75 and 150kg N/ha in all sampling stages. However, when N rate was increased to 225kg N/ha there was a decrease in height at 15WAS.

Plant height was also significantly affected with the first dose of 75kg P_2O_5 compared with the control. A further increase in phosphorus level to 150kg/ha, however, did not increase the plant height at all stages under study. This trend was recorded throughout the sampling periods of 6,9, 12 and 15 weeks after sowing. However, the application of 75 and 150kg P_2O_5/ha produced plant heights that were statistically higher than the control treatment.

Irrigation frequency significantly affected plant height of garlic at all sampling stages. At 6 weeks after sowing, there was a progressive decrease in plant height as irrigation interval was delayed from 5 to 15 days. In the other three stages, increasing interval from 5 to 10 or 15 days, significantly decreased plant height. However, the difference between 10 and 15 days was not statistically significant.

Significant nitrogen x phosphorus and nitrogen x irrigation interval interactions were recorded on plant height at 12 and 6 weeks samplings respectively (Table 2). Nitrogen x phosphorus interaction at 12 WAS revealed that at 0 level each of nitrogen and phosphorus, increasing other levels of either nitrogen or phosphorus has not increased plant height. However, at 75kg each of nitrogen and phosphorus, there was an increased in plant height. A further increase in nitrogen level, did not increase plant height but at 150kg of phosphorus there was an increase in plant height at all levels of N which was statistically at par with 75kg each of nitrogen and phosphorus.

Table 1: Plant height (cm) of garlic as influenced by levels of nitrogen, phosphorus and irrigation intervals during 1994/95 dry season at Samaru

Treatment(s)	6WAS	9WAS	12WAS	15WAS
Nitrogen (kgN/ha)				
0	17.40b	26.64b	33.09b	37.87b
75	21.05a	30.15a	38.78a	42.09a
150	21.45a	29.99a	36.30ab	38.47a
225	21.44a	28.84ab	34.02b	35.82b
SE±	0.290	0.87	1.42	1.38
Significance	*	**	**	**
Phosphorus (kg P_2O_5/ha)				
0	19.38b	27.50b	33.43b	36.31b
75	20.72a	29.64a	36.46a	39.31a
150	20.91a	29.58a	36.74a	40.07a
SE±	0.31	0.56	0.71	0.93
Significance	*	**	**	**
Irrigation Interval (day)				
5	22.00a	29.30a	38.98a	39.51a
10	20.40b	26.66b	34.28b	35.20b
15	18.61c	26.76b	33.38b	34.98b
SE±	0.25	0.75	1.23	1.20
Significance	*	**	**	**
Interactions				
N X P	NS	NS	**	NS
N X I	**	NS	NS	NS
P X I	NS	NS	NS	NS
N X P X I	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

The nitrogen x irrigation interval interaction (Table 2) on plant height revealed that when N rates are kept constant while comparing irrigation interval, the different irrigation treatments did not differ significantly on plant height under 0kgN/ha. However, at 75 and 150kgN/ha, the 5-day irrigation interval produced significantly taller plants than either 10 or 15 days intervals which were statistically at par. Under the highest rate of nitrogen (225kgN/ha) the plant height was observed to decrease with increase in number of days between irrigations. However, when irrigation treatments are held constant, while comparing the various nitrogen rates, it was observed that plant height was significantly increased with increase in nitrogen only upto 75KgN/ha beyond which no significant effect was recorded. This trend was recorded irrespective of the irrigation interval, except in the case of 15-day irrigation interval at the highest level of nitrogen (225kg/ha), where a reduction was recorded.

Table 2: Plant height as affected by nitrogen x phosphorus and nitrogen x irrigation interval at 12 and 6 WAS, during the 1994/95 dry season.

Treatments	Nitrogen (KgN/ha) 0	75	150	225
Phosphorus (kg P_2O_5/ha)		12WAS		
0	32.74cd	35.52bcd	35.33bcd	30.15d
75	32.56cd	42.46a	36.30bc	34.53bcd
150	33.96bcd	38.37ab	37.26abc	37.37abc
SE±	1.835			
Irrigation Interval (day)		6WAS		
5	17.25f	22.73abc	23.55ab	24.46a
10	17.82f	20.52de	21.20cde	22.06bcd
15	17.14f	19.89e	19.60e	17.82f
SE±	0.585			

Means followed by the same letter(s) within a set of interaction are not statistically different at 5% level of significance using DMRT.

4.1.2 Plant height, 1995/96

The mean plant height (cm) as influenced by nitrogen, phosphorus and irrigation interval and significance of interactions in 1995/96 dry season is shown in Table 3.

Application of nitrogen had significant effect on garlic plant height at all stages of sampling. At 6 weeks after sowing, the application of 75, 150 and 225Kg N/ha, significantly increased the plant height over the control although the differences within the levels were not significant. At 9 and 15WAS there was similar trend except, that the height was depressed at the highest level of nitrogen. However, at 12WAS, plant height increased with the initial level of 75kg N/ha. A further increase in N-level tended to depress the plant height.

Plant height at all stages was significantly affected by the application of phosphorus. The application of 75 and 150kg P_2O_5/ha though significantly superior to the control treatment, produced statistically similar plant heights at all stages of sampling.

Irrigation frequency was observed to have significant influence on plant height at various sampling stages. At 6 weeks after sowing, it was observed that there was a progressive decrease in plant height with increase in irrigation interval but in other stages of plant growth, 5 days irrigation interval produced taller

Table 3: Plant height (cm) of garlic as influenced by rates of nitrogen, phosphorus and irrigation intervals during 1995/96 dry season at Samaru

Treatment(s)	6WAS	9WAS	12WAS	15WAS
Nitrogen (kg N/ha)				
0	16.12b	23.91b	29.19c	33.86b
75	19.68a	27.28a	35.78a	38.37a
150	20.10a	26.99a	33.67ab	35.50a
225	20.11a	23.98b	31.16bc	32.82b
SE±	0.34	0.75	1.43	1.37
Significance	**	**	**	**
Phosphorus (kg P_2O_5/ha)				
0	18.03b	24.19b	30.37b	32.52b
75	19.42a	26.47a	33.43a	36.04a
150	19.55a	25.95a	33.55a	36.88a
SE±	0.29	0.49	0.75	0.87
Significance	**	**	**	**
Irrigation Interval (day)				
5	20.68a	26.28a	36.09a	38.69a
10	19.01b	24.04b	31.09b	34.41b
15	17.30c	24.30b	30.17b	38.74b
SE±	0.29	0.65	1.24	1.19
Significance	**	**	**	**
Interactions				
N X P	NS	NS	NS	NS
N X I	**	NS	NS	NS
P X I	NS	NS	NS	NS
N X P X I	NS	NS	NS	NS

Means followed by the same letter within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

plants than either 10 or 15-day irrigation interval, which were statistically at par.

Only nitrogen x irrigation interaction was observed to be highly significant on plant height at 6 WAS. (Table 4). Comparing the various nitrogen rates while keeping irrigation intervals constant, it was observed that plant height was significantly increased irespective of irrigation treatment, with increase in applied nitrogen only upto 75Kg N/ha. Further increase in applied nitrogen beyond 75Kg N/ha did not influence plant height significantly. Comparing the irrigation intervals while keeping nitrogen rates constant, it was observed that under 0kg N/ha, mean plant heights produced by the various irrigation treatments were statistically at par. However, further increase in applied- N to 75 and 150Kg N/ha, it revealed that the 5-day irrigation interval produced significantly taller plants than either 10 or 15-day irrigation intervals, which were found to be statistically at par, except at 225kg N/ha and 15-day irrigation interval where the plant height was observed to decrease.

Table 4: Plant height of Garlic as affected by Nitrogen x irrigation interval at 6WAS during 1995/96 season.

Treatments	Nitrogen (Kg N/ha) 0	75	150	225
Irrigation Interval (day)				
5	16.00f	21.38bc	22.23ab	23.12a
10	16.49f	19.08de	19.76cde	20.71bcd
15	15.86f	18.56e	18.71e	16.48f
SE±	0.559			

Means followed by the same letter(s) within a set of interaction are not statistically different at 5% level of significance using DMRT.

4.1.3 Plant height, 1996/97

Garlic plant height as affected by applied levels of nitrogen, phosphorus and irrigation frequency at different stages of crop growth is presented in Table 5.

The analysed data showed that application of 75, 150 and 225kg N/ha produced plant heights that were statistically at par at 6,9 and 15 WAS sampling periods, while the control treatment produced statistically shorter plants than these rates. At 12 WAS however, there was no significant difference between 75 and 150kg N/ha as well as between 0, 150 and 225Kg N/ha, respectively. There was also no significant difference between 0 and 225Kg N/ha at 15 WAS.

Differences due to phosphorus application were significant at all sampling periods. There was no significant difference between 75 and 150kg P_2O_5/ha in relation to plant height at all sampling stages, though the control treatment had consistently produced statistically shorter plants than 75 and 150kg P_2O_5/ha.

Irrigation frequency was also observed to have significant effects on plant height at all sampling periods. The plant height significantly decreased with each increase in irrigation interval at 6 WAS. In other stages, however, increasing the irrigation interval either to 10 or 15-day significantly decreased plant height. The difference between 10 and 15-day irrigation

Table 5: Plant height (cm) of garlic as affected by levels of nitrogen, phosphorus and irrigation intervals during 1996/97 dry season at Samaru

Treatment(s)	6WAS	9WAS	12WAS	15WAS
Nitrogen (kg N/ha)				
0	16.36b	20.74b	32.53b	37.22b
75	21.33a	27.90a	37.08a	43.18a
150	21.59a	27.34a	36.41ab	43.15a
225	20.93a	27.77a	37.82b	40.77ab
SE±	0.30	0.83	1.32	1.41
Significance	**	**	**	**
Phosphorus (kg P_2O_5/ha)				
0	18.38b	26.03b	33.94b	38.52b
75	20.85a	28.28a	36.96a	42.94a
150	20.94a	28.01a	37.47a	41.78a
SE±	0.25	0.53	0.94	0.95
Significance	**	**	**	**
Irrigation Interval (day)				
5	22.30a	29.46a	38.66a	42.69a
10	20.02b	26.95b	35.02b	38.92b
15	17.84c	25.91b	33.69b	38.63b
SE±	0.26	0.72	1.14	1.23
Significance	**	**	**	**
Interactions				
N X P	**	NS	NS	**
N X I	**	**	NS	NS
P X I	**	NS	NS	NS
N X P X I	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

intervals was not significant.

Nitrogen x phosphorus (at 6 and 15 WAS), nitrogen x irrigation (6 and 9 WAS) and phosphorus x irrigation (at 6 WAS) were all highly significant on plant height (Table 6 and 7). The nitrogen x phosphorus interaction (Table 6) at 6 WAS revealed that irrespective of phosphorus rate applied, plant height was significantly increased with increase in nitrogen rate only upto 75kg N/ha beyond which no significant increase was recorded. However, in the case of 0kg P_2O_5/ha plant height was increased upto 150kgN/ha. The application of 75 and 150kg P_2O_5/ha in combination with all rates of nitrogen produced statistically similar plant heights. Generally, the combination of 75kg P_2O_5/ha with 75kg N/ha produced plant height that was comparable to heights produced by the combined effects of the highest rate of phosphorus and nitrogen.

Nitrogen x phosphorus interaction on plant height at 15 WAS (Table 6) revealed that if in the absence of nitrogen increasing levels of phosphorus levels or vice-versa, the plant height was not affected significantly. However, increasing both nitrogen and phosphorus levels to 75kg/ha or more produced taller plants which were statistically similar, except at 225kg N/ha and 150kg P_2O_5/ha which produced shorter plants than 75kg P_2O_5/ha at 150kg N/ha and 150kg P_2O_5/ha at 75kg N/ha, respectively.

Table 6: Plant height (cm) as affected by Nitrogen x phosphorus and nitrogen x irrigation interval during 1996/97 season.

Treatments	Nitrogen (Kg N/ha) 0	75	150	225
Phosphorus (kg P_2O_5/ha)			6 WAS	
0	14.34g	18.86de	20.55bc	19.76cd
75	16.73f	22.51a	22.76a	21.39ab
150	18.01ef	22.63a	21.46ab	21.65ab
SE±	0.511			
Phosphorus (kg P_2O_5/ha)			15 WAS	
0	38.25cde	41.11cde	37.24e	37.49de
75	36.42e	43.81abc	47.79a	43.72abcd
150	36.99e	44.72ab	44.43abc	41.09cde
SE±	0.097			
Irrigation Interval (day)			6 WAS	
5	17.50gh	24.23a	23.45ab	24.02a
10	16.21hi	20.09de	22.43bc	21.35cd
15	15.37i	19.68ef	18.90fg	17.43gh
SE±	0.516			
Irrigation Interval (day)			9 WAS	
5	26.16c	31.00ab	27.95bc	32.74a
10	25.66c	26.38c	26.86c	25.88c
15	25.39c	26.33c	27.20bc	24.70c
SE±	1.440			

Means followed by the same letter(s) within a set of interaction are not statistically different at 5% level of significance using DMRT

Nitrogen x irrigation interval interaction on plant height at 6 and 9 WAS as shown in Table 6 indicated that at 6 WAS, the 5-day irrigation interval produced significantly taller plants than either 10 or 15-day interval, under all rates of N. At 0 and 75kg N/ha there was a significant decrease in plant height when irrigation interval was increased from 5 to 15-day. However at 150kg N/ha, the difference between 5 and 10-day irrigation interval was not significant a further increase in irrigation interval to 15 day has significantly reduced the plant height. At the highest levels of 225kg N/ha, there was a progressive decrease in plant height with each increase in irrigation interval.

Table 7: Plant height (cm) as affected by Phosphorus x Irrigation interval at 6WAS during 1996/97 season.

Treatments	Nitrogen (Kg N/ha) 0	75	150
Irrigation Interval (day)			
5	20.11cd	23.46a	23.32a
10	18.22e	21.18bc	20.66b
15	16.80f	17.90ef	18.83de
SE±	0.442		

Means followed by the same letter(s) are not statistically different at 5% level of significance using DMRT.

At 9 WAS, however, the Nitrogen x irrigation interval on plant height (Table 6) revealed that the 5-days irrigation interval was significantly superior to either 10 or 15-day interval at 75 and 225Kg N/ha, while statistically similar plant heights were recorded under 0, and 150kg N/ha, respectively. Comparing the various N-rates while keeping the irrigation treatments constant, the application of 75 and 225kg N/ha at 5-day irrigation interval, produced statistically similar values but were statistically taller than the control. However, with increase in the number of days between irrigation, the various nitrogen rates under study did not produced any significant variation in plant heights.

The significant phosphorus x irrigation interval interaction on plant height at 6WAS (Table 7) indicated that the application of 75 or 150kg P_2O_5/ha in combination with 5-day irrigation interval produced statistically taller plants than any combination. When the irrigation interval was increased to 10 days significant increase in plant height was only recorded when phosphorus level was increased from 0 to 75kg P_2O_5/ha over the control. At 15-day irrigation interval,the application of 150kg P_2O_5/ha produced statistically taller plants than the control. Comparing the irrigation intervals while keeping the phosphorus level constant, it was observed that there was a significant decrease in plant height with each increase in days between irrigation at all P-levels.

4.1.4 Mean number of leaves/plant, 1994/95

Data on mean leaf number per plant as affected by nitrogen, phosphorus and irrigation interval at 6, 9, 12 and 15 WAS and their interactions in 1994/95 dry season are presented in Table 8.

Results obtained showed that nitrogen application had significant effect on leaf number of garlic plant at all stages of sampling. At 6 WAS application of 150kg N/ha produced significantly higher number of leaves/plant than all other rates. It was also noted that 75kg N/ha was statistically superior to 225kg N/ha, which in turn produced significantly higher number of leaves/plant than the control treatment. At subsquent stages of growth, however, application of 75kg N/ha produced statistically higher number of leaves. Increasing nitrogen level to either 150 or 225kg N/ha, reduced the number of leaves/plant at 9 WAS. Both at 12 and 15WAS number of leaves/plant were not increased significantly when N rate was increased from 150 to 225kg N/ha. However, number of leaves per plant at 225kg N/ha was significantly lower than 75kg N/ha at 12 WAS.

Phosphorus application was also noted to have positive and significant effect on number of leaves per plant at all sampling periods. At all sampling stages of growth the number of leaves/plant produced under 0kg P_2O_5/ha was lower than the other two levels of applied

phosphorus, the difference of which was not significant statistically.

Frequency of irrigation also had significant effect on number of leaves per plant at all stages of sampling. At 6 WAS, there was a significant decrease in the number of leaves produced per plant with each increase in irrigation interval. However, at 9 and 15 WAS, no significant difference in leaf number/plant was recorded between 5 and 10 days as well as between 10 and 15 days irrigation intervals, respectively. Average leaf number par plant was, however, statistically higher with 5-day interval at 12 WAS, than 10 and 15 days irrigation intervals, which were statistically similar.

All first and second order interactions were not significant at all sampling periods.

Table 8: Mean number of leaves per plant as affected by rates of nitrogen, phosphorus and irrigation intervals during 1994/95 dry season at Samaru

Treatment(s)	6WAS	9WAS	12WAS	15WAS
Nitrogen (kg N/ha)				
0	3.28d	4.63b	8.14b	16.31b
75	4.14b	5.79a	9.86a	20.30a
150	4.82a	5.51b	9.03ab	18.11ab
225	3.81c	5.23b	8.76b	17.90ab
SE±	0.085	0.317	0.48	1.31
Significance	**	**	**	**
Phosphorus (kg P_2O_5/ha)				
0	3.87b	4.14b	7.94b	15.86b
75	4.18a	5.98a	9.08a	18.99a
150	3.99ab	5.73a	9.81a	19.61a
SE±	0.086	0.181	0.27	0.73
Significance	**	**	**	**
Irrigation Interval (day)				
5	4.46a	5.72a	9.59a	19.78a
10	4.03b	5.42ab	9.06b	18.15ab
15	3.55c	4.71b	8.18b	16.54b
SE±	0.074	0.274	0.41	0.93
Significance	**	**	**	**
Interactions				
N X P	NS	NS	NS	NS
N X I	NS	NS	NS	NS
P X I	NS	NS	NS	NS
N X P X I	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

.1.5 Mean number of leaves/plant, (1995/96)

The data on mean number of leaves per plant as affected by nitrogen, phosphorus and irrigation interval at 6, 9, 12 and 15 WAS and their interactions during 1995/96 season are presented in Table 9.

Application of nitrogen to garlic had significant effect on the number of leaves produced per plant at all stages of growth. At 6 WAS application of 75kg N/ha had produced significantly higher number ofleaves per plant than the control treatment at all sampling.A further increase in N-level to either 150 or 225kg/ha did not increase the number of leaves/plant at 9, 12 and 15WAS; depressed number of leaves at 6WAS.

Phosphorus application had significant effect on leaf number only at 9, 12 and 15 WAS. Number of leaves/plant was not significantly affected by P-levels at 6WAS. The application of 75 and 150kg P_2O_5/ha produced statistically similar leaf number per plant though significantly higher than the control at 9,12 and 15 WAS.

Irrigation interval was observed to have significant effect on leaf number per plant at all sampling periods. At 6WAS, there was a highly significant reduction in leaf number per plant with each increase in the number of days between irrigation. The number of leaves/plant significantly decreased when irrigation interval was increased from 5 days to either 10 or 15 days at 9 and 12

WAS. At 15WAS, there were significant reduction in leaf number/plant when irrigation interval was increased from 5 to 15 days.

None of the interactions were observed to be significant on leaf number per plant at all the sampling periods.

Table 9: Mean number of leaves per plant as affected by rates of nitrogen, phosphorus and irrigation intervals during 1995/96 dry season at Samaru

Treatment(s)	6WAS	9WAS	12WAS	15WAS
Nitrogen (kg N/ha)				
0	3.34b	4.03b	5.86b	10.42b
75	3.66a	5.33a	6.77a	14.32a
150	3.34b	5.02a	6.66ab	14.93a
225	3.32b	4.73ab	6.38ab	14.20a
SE±	0.07	0.30	0.28	1.14
Significance	**	**	**	**
Phosphorus (kg P_2O_5/ha)				
0	3.32	4.52b	5.13b	11.34b
75	3.54	5.36a	6.68a	14.23a
150	3.38	5.13a	6.43a	13.32ab
SE±	0.09	0.18	0.23	0.81
Significance	NS	**	**	**
Irrigation Interval (day)				
5	3.87a	5.75a	6.51a	14.77a
10	3.38b	4.77b	5.42b	13.53ab
15	2.99c	4.09b	5.32b	11.10b
SE±	0.06	0.26	0.24	0.99
Significance	**	**	**	**
Interactions				
N X P	NS	NS	NS	NS
N X I	NS	NS	NS	NS
P X I	NS	NS	NS	NS
N X P X I	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

.1.6 Mean number of leaves/plant 1996/97

The effect of nitrogen, phosphorus and irrigation interval on average number of leaves per plant at 6, 9, 12 and 15 WAS and their interactions during 1996/97 dry season is presented in Table 10.

The mean number of leaves per plant was significantly affected by the application of nitrogen throughout the growth stages of the crop. At 6 and 12 WAS, the application of 75kg N/ha resulted in higher number of leaves per plant than the control. However, at 9 and 15WAS, application of 75, 150 and 225kg N/ha produced higher number of leaves per plant than the control, though no statistical difference was recorded between 0 and 225kg N/ha at 9 WAS as well as 0, 150 and 225kg N/ha at 15 WAS, respectively.

Phosphorus application was also noted to have highly significant influence on mean number of leaves per plant at all sampling periods. At all stages of sampling, application of 75 and 150kg P_2O_5/ha produced same number of leaves per plant; while the control treatment produced statestically lower number of leaves plant than other treatments.

Frequency of irrigation was observed to significantly affect average member of leaves per plant at all periods of sampling. At 6 and 9 WAS, there was a progressive reduction in leaf number per plant with each

increase in irrigation interval. However, the number of leaves/plant produced at 12 and 15WAS days interval was significantly lower than 5-day irrigation interval.

Significant nitrogen x phosphorus and nitrogen x irrigation interval interactions were recorded only at 15 and 12 WAS, respectively (Table 11). The nitrogen x phosphorus interaction on average leaf number per plant at 15 WAS indicated that increasing either levels of N or P alone did not produce any significant effect on number of leaves per plant. However, when phosphorus and nitrogen levels were raised to 75kg each/ha significant increase in leaf number per plant was recorded. Increasing N-level beyond 75kg N/ha has significantly decreased the number of leaves/plant but aa6t 150kg P_2O_5/ha, increasing N-level beyond 150kg/ha, produced statistically similar number of leaves per

Table 10: Average number of leaves per plant as affected by rates of nitrogen, phosphorus and irrigation intervals during 1996/97 dry season at Samaru

Treatment(s)	6WAS	9WAS	12WAS	15WAS
Nitrogen (kg N/ha)				
0	3.59b	4.19b	7.53b	14.38b
75	4.10a	5.51a	9.18a	18.30a
150	3.90ab	5.39a	8.26ab	16.11ab
225	3.65b	5.02ab	7.64b	15.96ab
SE±	0.12	0.30	0.45	1.06
Significance	**	**	**	**
Phosphorus (kg P_2O_5/ha)				
0	3.35b	4.72b	7.19b	13.84b
75	3.99a	5.52a	8.33a	17.11a
150	3.78a	5.29a	8.93a	17.61a
SE±	0.10	0.18	0.27	0.56
Significance	**	**	**	**
Irrigation Interval (day)				
5	4.24a	5.81a	8.84a	17.81a
10	3.83b	4.99b	8.31ab	16.15ab
15	3.36c	4.13c	7.30b	14.60b
SE±	0.10	0.26	0.39	0.92
Significance	**	**	**	**
Interactions				
N X P	NS	NS	NS	**
N X I	NS	NS	**	NS
P X I	NS	NS	NS	NS
N X P X I	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

plant. Looking at the phosphorus levels while keeping the nitrogen rates constant, it was observed that at 0kgN/ha, there was no statistical difference between the various P levels under study. However, further increase in nitrogen level to 75kg N/ha, no significant difference between 75 and 150kg P_2O_5/ha was recorded, though they were statistically superior over the control. At higher levels of nitrogen (150 and 225kg N/ha), there was no significant difference between 0 and 75kg P_2O_5/ha as well as between 75 and 150kg P_2O_5/ha, respectively.

The significant nitrogen x irrigation interval interaction on leaf number per plant at 12WAS (Table 11) revealed that at 5-days irrigation interval, all applied levels of N produced statistically similar leaf number per plant, which was higher than the control treatment. Increasing the number of days between irrigation to either 10 or 15 days, produced no significant difference amongst the various N-rates tested with respect to average leaf number per plant. Comparing the various irrigation treatments while keeping the N-rates constant, it is observed that irrespective of applied-N under consideration, the 5 days irrigation interval produced statistically the highest number of leaves per plant than

Table 11: Nitrogen x phosphorus and nitrogen x irrigation interval interactions on number of leaves per plant at 15 and 12WAS, respectively during 1996/97 dry season.

Treatments	Nitrogen (Kg N/ha) 0	75	150	225
Phosphorus (kg P_2O_5/ha)			15 WAS	
0	14.19de	14.33de	14.04de	12.79e
75	14.22de	21.15a	16.81bcde	16.26bcde
150	14.74cde	19.41ab	17.48abcd	18.83abc
SE±	1.406			
Irrigation Interval (day)			12 WAS	
5	6.88bc	9.70a	9.34a	9.46a
10	5.23c	7.37b	6.81bc	6.83bc
15	5.48c	6.48bc	6.61bc	6.63bc
SE±	0.586			

Means followed by the same letter(s) within a set of interaction are not statistically different at 5% level of significance using DMRT.

either 10 or 15 days intervals, which were noted to be statistically at par as far as leaf number per plant is concerned.

4.1.7 Dry matter production (gm/plant), 1994/95

The effects of nitrogen, phosphorus and irrigation interval on dry matter production per plant at 6, 9, 12 and 15 WAS and their interactions during 1994/95 dry season is shown in Table 12.

Nitrogen significantly affected dry weight of garlic plant throughout the periods of sampling. At all sampling stages, dry matter production significantly increased with increasing rate of applied nitrogen from 0 to 75kg N/ha. There was, however, no significant difference between all rates of applied-N at 6 and 9 WAS. However at 12 and 15 WAS, 150 and 225kg N/ha produced lower dry matter than 75Kg N/ha, respectively.

Phosphorus application was also observed to influence dry matter production in garlic. Throughout the sampling period, dry matter production per plant was found to be significantly increased with the application of both 75Kg P_2O_5/ha and 150kg P_2O_5/ha over the control treatment. There was, however, no significant difference between 75 and 150kg P_2O_5/ha.

The effect of irrigation treatment on dry matter production at 6, 9, 12 and 15 WAS was significant. At 6 and 15WAS the 5 days irrigation interval produced

significantly higher dry matter/plant than 10 and 15 days intervals, which were observed to be statistically similar. At 9 WAS, however, 5 days irrigation interval produced significantly higher dry matter than 15 days interval. At 12 WAS, there was a progressive and significant reduction in plant dry matter produced with increase in days between irrigation from 5 to 15 days.

There were significant nitrogen x phosphorus and nitrogen x irrigation interaction on plant dry weight at 15, 9 and 12 WAS, respectively (Table 13). The nitrogen x phosphorus interaction at 15 WAS revealed that either the absence of nitrogen or phosphorus did not increase the dry matter production/plant significantly. At 75kg/ha of both N and P there was a significant increase in dry matter production per plant and this was statistically at par with all other levels of N and P. Comparing the phosphorus levels while keeping the nitrogen rates contant, it was observed that under the no nitrogen treatment, the phosphorus treatments did differ significantly in relation to plant dry matter production. At higher rates of applied nitrogen, the application of 75 and 150kg P_2O_5/ha produced statistically similar plant dry weights.

Table 12: Dry matter production (g/plant) as affected by rates of nitrogen, phosphorus and irrigation intervals during 1994/95 dry season at Samaru

Treatment(s)	6WAS	9WAS	12WAS	15WAS
Nitrogen (kg N/ha)				
0	0.935b	2.118b	3.437c	4.820c
75	1.133a	2.480a	4.108a	6.770a
150	1.183a	2.438ab	3.754b	6.020ab
225	1.123ab	2.272ab	3.516bc	5.640bc
SE±	0.07	0.11	0.08	0.32
Significance	*	*	*	*
Phosphorus (kg P_2O_5/ha)				
0	0.936b	2.005b	3.430b	4.850b
75	1.265a	2.605a	3.964a	6.410a
150	1.230a	2.371a	3.718a	6.190a
SE±	0.05	0.10	0.09	0.25
Significance	*	*	*	*
Irrigation Interval (day)				
5	1.364a	2.470a	4.114a	6.930a
10	1.049b	2.347ab	3.650b	5.240b
15	1.018b	2.164b	3.348c	5.270b
SE±	0.06	0.09	0.07	0.27
Significance	*	*	*	*
Interactions				
N X P	NS	NS	NS	**
N X I	NS	**	**	NS
P X I	NS	NS	NS	NS
N X P X I	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

The nitrogen x irrigation interval interaction on dry matter production at 9 WAS (Table 13) revealed that with 5-days irrigation interval, there was a significant increase in dry matter production per plant when nitrogen rate was increased from 0 to 75kg N/ha beyond which no significant increase was registered. Under 10 and 15 days irrigation interval no such differences were observed. When same N-level was examined across irrigation interval, 5-day irrigation interval resulted in higher dry matter production than 10 and 15-day intervals at all N-levels.

Table 13: Dry matter production (g/plant) as affected by nitrogen x phosphorus and nitrogen x irrigation interval at 15, 9 and 12WAS, respectively, during 1994/95 trial

Treatments	Nitrogen (Kg N/ha) 0	75	150	225
Phosphorus (kg P_2O_5/ha)			15 WAS	
0	4.22b	5.30b	5.71b	4.56b
75	5.03b	8.33a	7.51a	6.97ab
150	5.23b	6.88ab	8.24a	7.60a
SE±	0.513			
Irrigation Interval (day)			9 WAS	
5	1.914b	2.582a	2.483a	2.853a
10	1.593bc	1.872b	1.509bc	1.414bc
15	1.547bc	1.586bc	1.673bc	1.149c
SE±	0.183			
Irrigation Interval (day)			12 WAS	
5	3.616d	4.493a	4.138ab	4.209ab
10	3.597d	3.874bc	3.474de	3.456de
15	3.100ef	3.757bcd	3.650cd	2.883f
SE±	0.145			

Means followed by the same letter(s) within a set of interaction are not statistically different at 5% level of significance using DMRT.

The nitrogen x irrigation interval interaction on dry matter production/plant at 12 WAS (Table 13) has revealed that with 5-day irrigation interval, at 0kg N/ha resulted in significantly lower dry matter production than all other applied N-levels. However, when irrigation interval was increased to 10-day 75kg N/ha produced significantly higher plant dry matter than other rates. At 15-day interval however, 75 and 150kg N/ha produced higher dry matter than 0 and 225kg N/ha.

4.1.8 Dry matter production (gm/plant), 1995/96

Table 14 indicates the effect of nitrogen, phosphorus and irrigation interval on dry matter production per plant during 1995/96 dry season.

The effect of applied nitrogen on plant dry matter during the sampling periods was highly significant. At 6, 9 and 15 WAS increase in plant dry weight was significant only when nitrogen application was increased from 0 to either 75 or 150kg N/ha; further increase did not significantly increase dry matter production. There was even no statistical difference between 0 and 225kg N/ha. Increased application of nitrogen from 0 to 75kg N/ha significantly increased plant dry weight at 12 WAS sampling. Further increase in applied-N resulted in significant reduction in dry matter production.

Phosphorus application was also noted to have significantly affected dry matter production in garlic in

Table 14: Dry matter production (g/plant) as affected by rates of nitrogen, phosphorus and irrigation intervals during 1995/96 dry season at Samaru

Treatment(s)	6WAS	9WAS	12WAS	15WAS
Nitrogen (kg N/ha)				
0	0.636b	1.588b	2.827c	4.230c
75	1.133a	1.931a	3.679a	6.170a
150	1.165a	1.924a	3.335b	5.450ab
225	0.923ab	1.840ab	3.022c	5.060bc
SE±	0.10	0.09	0.10	0.31
Significance	**	**	**	**
Phosphorus (kg P_2O_5/ha)				
0	0.705b	1.523c	2.964b	4.270b
75	1.182a	2.082a	3.416a	5.820a
150	1.005a	1.857b	3.266a	5.590a
SE±	0.09	0.09	0.10	0.24
Significance	**	**	**	**
Irrigation Interval (day)				
5	1.134a	2.071a	3.654a	6.330a
10	0.824b	1.801b	3.168b	4.680b
15	0.835b	1.650b	2.823c	4.680b
SE±	0.09	0.08	0.08	0.27
Significance	**	**	**	**
Interactions				
N X P	NS	NS	NS	NS
N X I	NS	**	**	NS
P X I	NS	NS	NS	NS
N X P X I	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

all sampling periods. At 6, 12 and 15WAS, significant increase in plant dry matter was observed when phosphorus application was increased from 0 to 75 or 150kg P_2O_5/ha. At 9 WAS, however, 75kg P_2O_5/ha produced significantly more dry matter per plant than 150kg P_2O_5/ha, which in turn was also higher than the control treatment.

Irrigation interval had been found to affect plant dry matter at all sampling stages. At 6, 9 and 15 WAS, the 5-day irrigation interval produced statistically higher dry matter than both 10 and 15-day intervals, which were observed to be statistically similar. Plant dry weight at 12 WAS, however, was observed to significantly decrease with each increase in number of days between irrigation.

There was a significant nitrogen x Irrigation interaction on plant dry matter at 9 and 12 WAS, respectively (Table 15). At 9 WAS, the nitrogen x irrigation interaction revealed that comparing the various N-rates while keeping the irrigation treatments constant, at 5-day irrigation interval, a significant increase in dry matter production per plant was recorded only when applied N was increased from 0 to 75kg N/ha, beyond which no significant increase was obtained. However, when irrigation interval was increased to either 10 or 15-day, the various nitrogen rates did not register any significant differences, except at 225kg N/ha

Table 15: Dry matter production (g/plant) as affected by Nitrogen x irrigation interval at 9 and 12 WAS during 1995/96 dry season.

Treatments	Nitrogen (Kg N/ha) 0	75	150	225
Irrigation Interval (day)			9 WAS	
5	1.544bcd	2.859a	2.991a	2.450ab
10	1.832bc	1.948b	1.722bcd	1.703bcd
15	1.389c	1.785bcd	1.860bc	1.366d
SE±	1.163			
Irrigation Interval (day)			12 WAS	
5	3.031d	4.105a	3.726abc	3.7569a
10	2.975d	3.374bcd	3.098d	2.926de
15	2.474ef	3.254cd	3.180d	2.383f
SE±	0.166			

Means followed by the same letter(s) within a set of interaction are not statistically different at 5% level of significance using DMRT.

under 15 days irrigation interval, wherein the dry matter production was significantly reduced. Comparing the various irrigation treatments while keeping N-rates constant, it was revealed that the 5-day irrigation interval is statistically superior over the 10 and 15 days irrigation intervals irrespective of applied nitrogen rate, except under the control (0kg N/ha) where no statistical difference in relation to dry matter per plant, was recorded. Irrespective of applied nitrogen rate, there was also no significant difference between 10 and 15-day irrigation intervals.

At 12 WAS, the nitrogen x irrigation interval interaction on dry matter production per plant (Table 15) showed similar trend as obtained at 9 WAS, though the 5 and 10-day irrigation intervals produced statistically similar plant dry weights with the application of 0kg N/ha, while 15-day irrigation interval produced statistically the least dry matter per plant. Similarly, there was a significant reduction on plant dry matter with increase in number of days between irrrigation with the application of 225kg N/ha. However, at 75 and 150kg N/ha, the 5-day irrigation interval produced statistically the highest plant dry matter than 10 and 15-day intervals, which were statistically similar.
The various N-rates were statistically similar but statistically superior over the control, under 5-day

irrigation interval. Under 10-day irrigation interval, there was no statistical difference between all N rates tested. However, under 15-day irrigation interval, there was a significant increase in plant dry matter when applied N was increased from 0 to 75kg N/ha. Further increase to 225kg N/ha resulted in a significant reduction.

.9 Dry matter production (gm/plant), 1996/97

The effect of nitrogen, phosphorus and irrigation interval on dry matter production per plant during 1996/97 dry season is presented in Table 16.

Nitrogen application had significant influence on dry matter production of garlic at all sampling periods. At 6 WAS, no significant difference in dry matter per plant was recorded amongst the various applied rates of nitrogen though these rates were statistically superior to the control treatment. Similar trend was recorded at 9 and 15 WAS, though the control treatments and 225kg N/ha were statistically similar. At 12 WAS, however, 75kg N/ha produced significantly higher dry matter per plant than all rates tested; this was followed by 150 and 225kg N/ha. Application of phosphorus has also significantly affected dry matter production at all periods of sampling. There was no significant difference between 75 and 150kg P_2O_5/ha at all stages of crop growth, though statistically lowest dry matter was recorded under the control plots.

Table 16: Dry matter production (g/plant) as affected by rates of nitrogen, phosphorus and irrigation intervals during 1996/97 dry season at Samaru

Treatment(s)	6WAS	9WAS	12WAS	15WAS
Nitrogen (kg N/ha)				
0	0.821b	1.905b	3.260c	4.710b
75	1.156a	2.205a	3.988a	6.560a
150	1.105a	2.217a	3.635b	5.930a
225	1.055a	2.114ab	3.381bc	5.470ab
SE±	0.06	0.10	0.09	0.37
Significance	**	**	**	**
Phosphorus (kg P_2O_5/ha)				
0	0.886b	1.836b	3.302b	4.750b
75	1.116a	2.358a	3.804a	6.240a
150	1.100a	2.152a	3.591a	6.020a
SE±	0.05	0.10	0.09	0.26
Significance	**	**	**	**
Irrigation Interval (day)				
5	1.322a	2.309a	3.957a	6.780a
10	0.968b	2.111ab	3.535b	5.170b
15	0.812c	1.925b	3.205c	5.060b
SE±	0.05	0.09	0.08	0.32
Significance	**	**	**	**
Interactions				
N X P	NS	NS	NS	NS
N X I	NS	**	**	NS
P X I	NS	NS	**	NS
N X P X I	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

There was a significant reduction in dry matter production per plant with increase in number of days between irrigations at 6 and 12 WAS. Dry matter production at 5-day irrigation interval was significantly higher than 15-day interval at 9 WAS and 10-day irrigation interval at 15 WAS, respectively.

Significant nitrogen x irrigration interval (at 9 and 12 WAS) as well as phosphorus x irrigation interval interactios (at 12 WAS) were recorded on plant dry weight. The nitrogen x irrigation interval interaction on plant dry matter at 9 WAS (Table 17) indicated that the application of 75, 150 and 225kg N/ha produced plant dry matter that are statistically similar when 5 and 10-day irrigation intervals, were considered, respectively. The control treatment produced statistcally the lowest plant dry matter, irrespective of irrigation treatment considered, though it was similar statistically with the application of 225kg N/ha when 15-day irrigation interval was adopted. Considering the various irrigation treatments while keeping nitrogen treatments constant, it was observed that the 5-day irrigation interval was statistically superior over the 10 and 15-day irrigation intervals with respect to plant dry weight at all rates of nitrogen, except under the control (0kg N/ha) where no statistical difference between the irrigation treatments was registered.

Table 17: Dry matter production (g/plant) as affected by Nitrogen x irrigation interval and phosphorus x irrigation interval at 9 and 12 WAS during 1996/97 dry season.

Treatments	irrigation interval (day) 5	10	15
Nitrogen (Kg N/ha)		9 WAS	
0	1.844cd	1.641d	1.689d
75	2.359a	2.108b	2.007bc
150	2.382a	2.022bc	2.049bc
225	2.550a	1.934bc	1.657d
SE±	0.072		
Nitrogen (Kg N/ha)		12 WAS	
0	3.330cd	3.475c	2.974de
75	4.416a	3.974ab	3.574bc
150	4.026a	3.398cd	3.480c
225	4.056a	3.293cd	2.7944e
SE±	0.150		
Phosphorus (kg P_2O_5/ha)		12 WAS	
0	3.223cd	3.155cd	2.928d
75	4.197a	3.914ab	3.303cd
150	3.851ab	3.537bc	3.386c
SE±	0.152		

Means followed by the same letter(s) within a set of interaction are not statistically different at 5% level of significance using DMRT.

There was also no significant difference between plant dry weights produced under 10 and 15-day irrigation intervals at all levels of applied nitrogen with the exception of 225kg N/ha where 10-day irrigation interval was statistically higher than 15-day interval.

At 12 WAS, the nitrogen x irrigation interaction on plant dry matter (Table 17) revealed that comparing the various N-rates while keeping the irrigation treatments constant, the application of 75, 150 and 225kg N/ha produced plant dry matter that were statistically similar though significantly higher than the control (0kg N/ha) treatment when 5-day irrigation interval was considered. With 10-day irrigation frequency, application of 75kg N/ha produced significantly higher plant dry matter than all other treatments, while 0, 150 and 225kg N/ha produced statistically same plant dry matter. Under 15-day irrigation interval, application of 0 and 225kg N/ha as well as 75 and 150kg N/ha produced statistically same plant dry matter, respectively; while the former were statistically inferior over the later. Comparing the irrigation treatments while keeping N-rates constant, it was observed that under 0kg N/ha, 5 and 10-day irrigation intervals produced statistically same plant dry matter, though significantly higher than that obtained with 15-day interval. At 75kg N/ha, there was signigicant decrease in plant dry matter production when irrigation

interval was increased from 5 to 15 days. When 150kg N/ha was considered, it was observed that 5-day irrigation interval was statistically superior over 10 and 15-day intervals respectively while no statistical difference between 10 and 15-day intervals was recorded. Considering 225kg N/ha, it was observed that plant dry matter significantly decreased with each increase in number of days between irrigations.

The phosphorus x irrigation interaction on plant dry matter (at 12 WAS) as indicated on table 17 revealed that at 0kg P_2O_5/ha there was no statistical difference between the various irrigation treatments. However, with the application of either 75 or 150kg P_2O_5/ha, there was no significant difference between 5 and 10-day irrigation intervals. There also no significant difference between 10 and 15-day irrigation intervals under 150kg P_2O_5/ha, though significant difference was recorded between these treatments under 75kg P_2O_5/ha. Comparing the various phosphorus rates while keeping the irrigation treatments constant, it was observed that the application of 75 and 150kg P_2O_5/ha produced statistically similar plant dry matter irrespective of irrigation interval considered. It was also observed that the application 0kg P_2O_5/ha produced statistically the lowest plant dry matter under all irrigation treatments except with 15-day irrigation interval, where no significant difference was recorded between 0 and 75kg P_2O_5/ha.

..10 Crop growth Rate of garlic (gldm^2/wk), 1994/95

The effect of nitrogen, phosphorus levels and irrigation interval on crop growth rate during 1994/95 dry season is presented in Table 18.

Application of varying rates of nitrogen had significantly affected garlic growth rate at all sampling stages. CGR was higher at 75kg N/ha at all stages of growth and was statistically similar with 150kg N/ha. The difference between 150 and 225kg N/ha was not significant and was similar statistically with the control except at 6 and 9 WAS where the control produced significantly lower CGR than 150 KgN/ha.

Phosphorus application was also observed to have significant effect on garlic growth rate at all stages of sampling. At all stages, the CGR increased significantly when phosphorus level was increased from 0 to 75kg P_2O_5/ha. A further increase in P-level to 150kg P_2O_5/ha, however, did not increase the CGR.

Freqeuncy of irrigation had significant influence on crop growth rate throughout the growth stages of the crop (Table 18). The 5-day irrigation interval had persistently produced significantly higher crop growth rate than either 10 or 15-day intervals, which were statistically similar at all sampling periods.

None of the first or second order interactions was significant throughout the sampling periods.

Table 18: Crop growth rate ($g/dm^2/wk$) as affected by rates of nitrogen, phosphorus and irrigation intervals during 1994/95 dry season at Samaru

Treatment(s)	6WAS	9WAS	12WAS	15WAS
Nitrogen (kg N/ha)				
0	0.1559c	0.302b	0.430b	0.462b
75	0.2222a	0.472a	0.543a	0.887a
150	0.1973ab	0.418a	0.451ab	0.756ab
225	0.1872bc	0.383ab	0.435b	0.709b
SE±	0.011	0.038	0.034	0.100
Significance	**	**	**	**
Phosphorus (kg P_2O_5/ha)				
0	0.1560b	0.256b	0.328b	0.472b
75	0.2110a	0.445a	0.453a	0.814a
150	0.2050a	0.380a	0.450a	0.824a
SE±	0.009	0.034	0.028	0.083
Significance	**	**	**	**
Irrigation Interval (day)				
5	0.2274a	0.469a	0.548a	0.938a
10	0.1748b	0.331b	0.455b	0.531b
15	0.1698b	0.361b	0.428b	0.641b
SE±	0.009	0.035	0.030	0.086
Significance	**	**	**	**
Interactions				
N X P	NS	NS	NS	NS
N X I	NS	NS	NS	NS
P X I	NS	NS	NS	NS
N X P X I	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

4.1.11 Crop growth rate of garlic (g/dm²/wk), 1995/96

The effect of nitrogen, phosphorus levels and irrigation interval on crop growth rate during 1995/96 dry season is presented in Table 19.

At 6 WAS, the CGR was higher at 75kg N/ha when compared with other N-levels except 150kg N/ha. It was followed by 150 and 225kg N/ha, which were similar statistically but higher than the control. The CGR at 9 and 15 WAS responded similarly. As N-level was increased from 0 to 75kg N/ha, there was an increase in CGR. A further increase in N-level however, did not affect the CGR. The control produced lower CGR than all other treatments of applied N at 9 WAS; but at 15 WAS, it was significantly lower than 75kg N/ha only. At 12 WAS, 75kg N/ha produced higher CGR than all other levels of N, which were statistically similar with one another.

Effect of phosphorus was signifcant on crop growth rate except at 9 WAS. At these samplings, statistically least crop growth rate was recorded with the control treatment while no significant difference between 75 and 150kg P_2O_5/ha was recorded.

The effect of irrigation interval on crop growth rate was significant throughout the stages of crop growth. The 5-day irrigation interval had produced significantly higher crop growth rate than 10 and 15-day interval, which were statistically similar at all sampling periods.

Table 19: Crop growth rate (g/dm²/wk) as affected by rates of nitrogen, phosphorus and irrigation intervals during 1995/96 dry season at Samaru

Treatment(s)	6WAS	9WAS	12WAS	15WAS
Nitrogen (kg N/ha)				
0	0.100c	0.138b	0.310b	0.351b
75	0.189a	0.260a	0.437a	0.624a
150	0.163ab	0.235a	0.353b	0.529ab
225	0.154b	0.229a	0.301b	0.509ab
SE±	0.011	0.026	0.024	0.075
Significance	**	**	**	**
Phosphorus (kg P_2O_5/ha)				
0	0.118b	0.204	0.260b	0.326b
75	0.174a	0.260	0.338a	0.602a
150	0.163a	0.213	0.353a	0.582a
SE±	0.009	0.024	0.021	0.060
Significance	**	**	**	**
Irrigation Interval (day)				
5	0.189a	0.299a	0.411a	0.669a
10	0.132b	0.208b	0.346b	0.378b
15	0.133b	0.214b	0.293b	0.464b
SE±	0.009	0.023	0.021	0.065
Significance	**	**	**	**
Interactions				
N X P	NS	NS	NS	NS
N X I	NS	NS	NS	NS
P X I	NS	NS	NS	NS
N X P X I	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

No significant interaction on crop growth rate at all stages of sampling during the 1995/96 trial.

1.12 Crop growth rate of garlic (g/dm^2/wk), 1996/97

The effect of nitrogen, phosphorus levels and irrigation interval on crop growth rate during 1996/97 dry season is shown in Table 20.

All rates of applied-N recorded crop growth rates that were statistically similar at 6, 9 and 15 WAS. At 12WAS application of 75kg N/ha produced significantly higher CGR than other treatments, which were statistically similar.

At all the sampling stages, application of 75 and 150kg P_2O_5/ha had produced statistically same CGR, though significantly higher than 0kg P_2O_5/ha.

The 5-day irrigation interval had recorded significantly higher CGR than either 10 or 15-day intervals at 6, 9 and 15WAS samplings. It was also observed that at these sampling periods, 10 and 15-day irrigation intervals produced statistically similar CGR. At 12WAS, however, there was no significant difference in CGR between 5 and 10-day as well as 10 and 15-day irrigation intervals, respectively.

None of the first and second order interactions was found to have significant effect on CGR at all sampling stages.

Table 20: Crop growth rate (g/dm²/wk) as affected by rates of nitrogen, phosphorus and irrigation intervals during 1996/97 dry season at Samaru

Treatment(s)	6WAS	9WAS	12WAS	15WAS
Nitrogen (kg N/ha)				
0	0.1368b	0.268b	0.445b	0.484b
75	0.1927a	0.350ab	0.592a	0.860a
150	0.1841a	0.371a	0.472b	0.766ab
225	0.1757a	0.353ab	0.425b	0.701ab
SE±	0.011	0.034	0.033	0.116
Significance	**	**	**	**
Phosphorus (kg P_2O_5/ha)				
0	0.1476b	0.217b	0.387b	0.483b
75	0.1836a	0.414a	0.484a	0.815a
150	0.1857a	0.351a	0.479a	0.810a
SE±	0.008	0.032	0.028	0.083
Significance	**	**	**	**
Irrigation Interval (day)				
5	0.2203a	0.389a	0.549a	0.942a
10	0.1613b	0.281b	0.477ab	0.544b
15	0.1353b	0.271b	0.424b	0.623b
SE±	0.009	0.029	0.029	0.101
Significance	**	**	**	**
Interactions				
N X P	NS	NS	NS	NS
N X I	NS	NS	NS	NS
P X I	NS	NS	NS	NS
N X P X I	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

4.1.13 Relative growth rate (g/g/wk) 1994/95

The influence of nitrogen, phosphorus levels and irrigation interval on RGR of garlic during the 1994/95 dry season is shown in Table 21.

The application of nitrogen has significantly influenced RGR of garlic crop throughout the sampling stages. All rates of applied-N produced statistically similar RGR throughout the growth period of the crop, and they were significantly higher than the control at 9 WAS but only 75kg N/ha produced higher RGR than the control at 12 and 15 WAS.

Phosphorus application affected the crop's relative growth rate at all growth stages. Results indicated that the application of either 75 or 150kg P_2O_5/ha significantly increased RGR over the control treatment, and the difference within the applied levels of P was not significant at all sampling periods.

Irrigation interval was also observed to have positive effects on RGR. Throughout the sampling periods, RGR at 5-day irrigation interval was higher than both 10 and 15-day, which were statistically similar.

None of the interactions was observed to be significant on RGR at all stages of sampling.

Table 21: Relative growth rate (g/g/wk) as influenced by rates of nitrogen, phosphorus and irrigation intervals during 1994/95 dry season at Samaru

Treatment(s)	9WAS	12WAS	15WAS
Nitrogen (kg N/ha)			
0	0.1463b	0.1214b	0.1005b
75	0.2508a	0.1729a	0.1539a
150	0.2299a	0.1538ab	0.1407ab
225	0.2173a	0.1544ab	0.1342ab
SE±	0.021	0.013	0.014
Significance	**	**	**
Phosphorus (kg P_2O_5/ha)			
0	0.1350b	0.1064b	0.0833b
75	0.2236a	0.1474a	0.1425a
150	0.2121a	0.1530a	0.1512a
SE±	0.016	0.012	0.012
Significance	**	**	**
Irrigation Interval (day)			
5	0.1938a	0.1734a	0.1559a
10	0.1424b	0.1351b	0.1060b
15	0.1355b	0.1283b	0.1051b
SE±	0.017	0.011	0.012
Significance	**	**	**
Interactions			
N X P	NS	NS	NS
N X I	NS	NS	NS
P X I	NS	NS	NS
N X P X I	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

.1.14 Relative growth rate (g/g/wk) 1995/96

The effect of nitrogen, phosphorus levels and irrigation interval on Relative growth rate (RGR) of garlic during the 1995/96 dry season is shown in Table 22.

Nitrogen had produced significant effect on RGR of garlic at 9 and 12WAS samplings. At 9 WAS, application of 75kg N/ha produced significantly higher RGR than all other levels and higher than the control at 12 WAS, the other applied-N levels were statistically similar. No significant difference was racorded between all N rates tested at 15 WAS.

Phosphorus application was observed to have influenced RGR at all sampling stages. At 9 and 15WAS sampling, RGR was found to be higher with the aplication of 75kg P_2O_5/ha than the control. At 12 WAS, however, application of 150kg P_2O_5/ha produced significantly higher RGR than the control, while 75 and 150kg P_2O_5/ha were statistically similar.

Irrigation interval had been observed to have no significant effect on RGR at 9 WAS. However, at 12 and 15 WAS, the 5-day irrigation interval produced statistically higher RGR than either 10 or 15-day irrigation intervals, which are statistically similar.

None of the various interactions was significant on RGR throughout the sampling periods.

Table 22: Relative growth rate (g/g/wk) as influenced by rates of nitrogen, phosphorus and irrigation intervals during 1995/96 dry season at Samaru.

Treatment(s)	9WAS	12WAS	15WAS
Nitrogen (kg N/ha)			
0	0.1128b	0.1066b	0.1003
75	0.2221a	0.1614a	0.1210
150	0.1636b	0.1396ab	0.1088
225	0.1665b	0.1367ab	0.1100
SE±	0.018	0.013	0.017
Significance	**	**	NS
Phosphorus (kg P_2O_5/ha)			
0	0.1194b	0.1027b	0.0816b
75	0.1725a	0.1314ab	0.1414a
150	0.1519ab	0.1442a	0.1183ab
SE±	0.014	0.011	0.014
Significance	*	*	*
Irrigation Interval (day)			
5	0.1455	0.1511a	0.1473a
10	0.1618	0.1083b	0.0872b
15	0.1664	0.1088b	0.1007b
SE±	0.015	0.011	0.015
Significance	NS	*	*
Interactions			
N X P	NS	NS	NS
N X I	NS	NS	NS
P X I	NS	NS	NS
N X P X I	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

4.1.15 Relative growth rate (g/gwk) 1996/97

Table 23 shows the effect of nitrogen, phosphorus levels and irrigation interval on the RGR of garlic during the 1996/97 dry season.

Nitrogen fertilization had significant effect on the RGR of galic at 9 and 12 WAS, respectively. All levels of applied N resulted in higher RGR than the control at 9 WAS. At 12 WAS, 75 and 225kg N/ha were found to produce higher RGR than the control, while no significant difference was observed between control and 150kg N/ha.

Phosphorus application was also observed to have significant effect on RGR at all stages of sampling. The application of 75 and 150kg P_2O_5/ha produced statistically similar RGR values, but statistically superior over the control. The trend was recorded at all stages of sampling.

Irrigation interval did not affect RGR significantly at 9 WAS. However, the effect of irrigation was significant at 12 and 15 WAS, wherein 5-day irrigation interval resulted in higher RGR when compered 15-day irrigation interval.

None of the various interactions was significant on RGR at all sampling stages.

Table 23: Relative growth rate (g/g/wk) as influenced by rates of nitrogen, phosphorus and irrigation intervals during 1996/97 dry season at Samaru.

Treatment(s)	9WAS	12WAS	15WAS
Nitrogen (kg N/ha)			
0	0.1463b	0.1263b	0.1091
75	0.2242a	0.1787a	0.1536
150	0.2208a	0.1668ab	0.1482
225	0.2241a	0.1699a	0.1405
SE±	0.020	0.014	0.019
Significance	*	**	NS
Phosphorus (kg P_2O_5/ha)			
0	0.1320b	0.1118b	0.1013b
75	0.2369a	0.1668a	0.1480a
150	0.2176a	0.1752a	0.1543a
SE±	0.015	0.013	0.012
Significance	**	**	**
Irrigation Interval (day)			
5	0.1788	0.1614a	0.1593a
10	0.1885	0.1287ab	0.1130ab
15	0.1692	0.1238b	0.1013b
SE±	0.018	0.012	0.016
Significance	NS	*	*
Interactions			
N X P	NS	NS	NS
N X I	NS	NS	NS
P X I	NS	NS	NS
N X P X I	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

.1.16 Number of days to maturity.

The effects of nitrogen, phosphorus levels and irrigation interval on number of days to maturity of garlic during 1994/95, 1995/96 and 1996/97 as well as in the combined analysis is shown on Table 24.

Nitrogen application has significantly affected number of days to maturity of garlic. The highest level of N (225kg/ha) took significantly longer days to maturity when compared with the control and 75kg N/ha throughout the 3 seasons trial. The control treatment reached maturity earlier than 75kg N/ha. In the case of combined analysis, each increase in the level of N, from 0 to 225kg N/ha, significantly delayed maturity.

Phosphorus application has significantly affected the number of days to maturity of garlic crop. Throughout the 3 season trials and in the combined analysis, there was significant increase in number of days to maturity with increase in phosphorus application up to 75kg P_2O_5/ha, beyond which there was no further increase in number of days to maturity.

The effect of irrigation interval on days to maturity was also significant. Throughout the 3 year investigation and in the combined analysis, there was a progressive and significant reduction in the number of days to maturity with increase in the number of days between irrigations.

All first order interaction were found to be highly significant in combined analysis, whereas nitrogen x irrigation interaction were significant during 1994/95 and 1996/97 dry seasons (Table 25). The nitrogen x phosphorus interaction on number of days to maturity as obtained in the combined analysis (Table 25) indicated that comparing the various nitrogen treatments while keeping the phosphorus levels constant, at 0 and 75kg P_2O_5/ha there was a significant increase in days to maturity with increase in applied nitrogen upto 150kg N/ha beyond which no significant increase was recorded. However, at 150kg P_2O_5/ha, the increase in days to maturity was up to 225kg N/ha. Comparing the various phosphorus levels while keeping the nitrogen treatments constant, it was observed that significant increase in number of days to maturity was recorded when phosphorus level was increased from 0 to 75kg P_2O_5/ha only, under 0, 75 and 225kg N/ha; further increase to 150kg P_2O_5/ha did not produce significant effect. However, under 150kgN/ha, application of phosphorus beyond 75kg P_2O_5/ha resulted in a significant reduction in number of days to maturity which was similar with the control treatment (Table 25).

Table 24: Number of days to maturity as affected by varying levels of nitrogen, phosphorus and irrigation intervals during 1994/95, 1995/96 and 1996/97 dry seasons at Samaru.

Treatment(s)	1994/95	1995/96	1996/97	Combined
Nitrogen (kg N/ha)				
0	103.44c	95.44c	102.85c	100.58d
75	107.78bc	102.00b	107.11b	105.63c
150	111.33ab	105.33ab	110.63ab	109.10b
225	114.00a	107.96a	113.41a	111.79a
SE±	1.49	1.50	1.38	0.84
Significance	**	**	**	**
Phosphorus (kg P_2O_5/ha)				
0	105.06b	98.56b	104.44b	102.69b
75	111.64a	105.19a	111.03a	109.29a
150	110.72a	104.31a	110.03a	108.35a
SE±	1.10	1.11	1.28	0.67
Significance	**	**	**	**
Irrigation Interval (day)				
5	118.69a	112.31a	118.06a	116.35a
10	110.44b	102.92b	109.83b	108.06b
15	98.28c	91.83c	97.61c	95.91c
SE±	1.29	1.30	1.20	0.73
Significance	**	**	**	**
Interactions				
N X P	NS	NS	NS	**
N X I	**	NS	**	**
P X I	NS	NS	NS	**
N X P X I	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

The significant nitrogen x irrigation interval interaction on days to maturity in 1994/95 trial (Table 25) indicated that under the 5-day irrigation interval all applied nitrogen treatments produced statistically similar number of days to maturity. Similarly, under the longest irrigation interval of 15-day, there was no significant difference between all rates of nitrogen under study with respect to number of days to maturity except at 225kg N/ha. However, with 10-day irrigation interval, significant increase in number of days to maturity was recorded when nitrogen rate was increased from 0kg N/ha to 75kg N/ha beyond which no significant increase was recorded. A study of the various irrigation treatments at the same rate of applied nitrogen, revealed that the 5-day irrigation interval produced statistically more number of days to maturity than 15-day irrigation interval except only under 0kg N/ha. Under 75, 150 and 225kg N/ha, the 5 and 10-day irrigation intervals produced statistically similar number of days to maturity while the 15-day intervel produced statistically the lowest number of days to maturity.

In the 1996/97 trial, the significant nitrogen x irrigarion interval on number of days to maturity (Table 25) revealed that under 5-day irrigation interval, there was a significant increase in number of days to maturity when nitrogen rate was increased from 0 to 75kg N/ha beyond which there was no significant effect.

Table 25: Number of days to maturity of garlic as affected by Nitrogen x Phosphorus and nitorgen x irrigation interval during 1994/95 and 1996/97 trials as well as combined analysis, respectively.

Treatments	Nitrogen (Kg N/ha) 0	75	150	225
Phosphorus (kg P_2O_5/ha)		Combined		
0	96.44d	101.11c	107.11b	106.07bc
75	103.07c	107.52b	112.89a	113.67a
150	102.22c	108.26b	107.30b	115.63a
SE±	1.384			
Irrigation Interval (day)		1994/95		
5	95.67e	115.78ab	121.67a	121.67a
10	99.22de	111.33bc	116.00ab	115.22ab
15	95.44e	96.22e	96.33e	105.11cd
SE±	2.574			
Irrigation Interval (day)		1996/97		
5	105.22cd	115.11ab	120.89a	121.00a
10	98.56de	110.67bc	115.33ab	114.78ab
15	94.78e	95.56e	95.67e	104.44cd
SE±	2.390			
Irrigation Interval (day)		Combined		
5	112.85b	113.70b	119.41a	119.44a
10	96.33e	109.11c	113.78b	113.04b
15	92.56e	94.07e	94.11e	102.89d
SE±	1.455			

Table 26: Number of days to maturity of garlic as affected by phosphorus x irrigation interval in the combined analysis.

Treatments	Phosphorus (kg P_2O_5/ha) 0	75	150
Irrigation Interval (day)			
5	104.28d	117.22a	117.56a
10	105.33cd	110.03b	108.83bc
15	88.84f	100.61e	98.67e
SE±	1.198		

Means followed by the same letter(s) within a set of interaction are not statistically different at 5% level of probability using DMRT.

Similar trend was observed under 10-day irrigation interval. However, under the 15-day irrigation interval, significant increase in days to maturity was recorded when applied nitrogen was raised from 150 to 225kg N/ha. Comparing the various irrigation treatments while keeping the nitrogen treatments constant, it was observed that irrespective of nitrogen rate considered, there was no statistical difference between 5 and 10-day irrigation intervals with respect to number of days to maturity; while the 15-day irrigation intervals produced statistically the lowest number of days to maturity at all rates of applied nitrogen except under 0kg N/ha.

The significant nitrogen x irrigation interval interaction on days to maturity as obtained in the combined analysis (Table 25) revealed that under the 5-day irrigation interval, the difference between 0 and 75kg N/ha and 150 and 225kg N/ha was not significant. When 10-day irrigation interval was considered, the number of days to maturity was observed to significantly increase with increase in applied nitrogen but up to 150kg N/ha, beyond which no further significant increase was recorded. Under the 15-day irrigation interval however, the application of 0, 75 and 150kg N/ha was not significant, while 225kg N/ha produced statistically more days to maturity than the other 3 N-rates. Comparing the various irrigation treatments, while keeping the nitrogen

rates constant, it was observed that the 5-day irrigation interval produced statistically the highest number of days to maturity than either 10 or 15-day intervals irrespective of nitrogen rate considered. It was also observed that the 10-day irrigation interval produced significantly more days to maturity than the 15-day irrigation interval under all rates of applied nitrogen except under 0kg N/ha where there was no statistical difference between the two treatments.

The significant phosphorus x irrigation interval interaction on number of days to maturity as observed in the combined analysis (Table 26) indicated that the various applied phosphorus rates produced statistically similar number of days to maturity when 5-day irrigation interval was put under consideration. Under 10 and 15-day irrigation intervals, however, significant increase in number of days to maturity was recorded only when phosphorus level was raised from 0 to 75kg P_2O_5/ha beyond which no significant effect was recorded. Comparing the various irrigation treatments while keeping the phosphorus levels constant, it was observed that irrespective of phosphorus level considered, there was a and significant reduction in the number of days to maturity with every increase in number of days between irrigations except at 0kg P_2O_5/ha.

4.2. Effect of nitrogen phosphorus and irrigation interval on yield components and bulb yield of garlic.

4.2.1 Mean number of cloves/bulb.

The effect of nitrogen, phosphorus levels and irrigation interval on mean number of cloves bulb during 1994/95, 1995/96 and 1996/97 dry season and in the combined analysis is presented in table 27.

The application of nitrogen had significant effect on clove number/bulb throughout the experimental seasons. There was a significant increase in the number of cloves/bulb with increase in applied-N from 0 to 75Kg N/ha beyond which there was statistically no significant increase. This trend was observed in all years of study as well as in the combined analysis.

The effect of phosphorus on number of cloves/bulb was also significant. In 1996/97 trials no significant difference was recorded between 0 and 150kg P_2O_5/ha as well as between 75 and 150kg P_2O_5/ha though 75kg P_2O_5/ha was statistically higher than the control. In 1994/95 and 1995/96 trials and the combined analysis, however, application of 75 and 150kg P_2O_5/ha produced statistically similar number of cloves/bulb, while the control treatment produced statistcally the lowest clove number per bulb.

Table 27: Number of cloves/bulb as affected by varying levels of nitrogen, phosphorus and irrigation intervals during 1994/95 1995/96 and 1996/97 dry seasons at Samaru

Treatment(s)	1994/95	1995/96	1996/97	Combined
Nitrogen (kg N/ha)				
0	11.31b	9.54b	11.81b	10.89b
75	28.67a	21.46a	28.31a	26.15a
150	29.17a	21.72a	28.99a	26.62a
225	29.78a	23.41a	29.58a	27.59a
SE±	0.69	2.24	0.82	0.83
Significance	**	**	**	**
Phosphorus (kg P_2O_5/ha)				
0	19.52b	16.45b	23.24b	19.74b
75	26.53a	19.53a	26.18a	24.08a
150	24.90a	20.12a	24.59ab	23.20a
SE±	0.57	0.92	0.54	0.40
Significance	**	**	**	**
Irrigation Interval (day)				
5	26.82a	21.09a	26.50a	24.80a
10	24.97b	18.88b	24.64ab	22.83b
15	23.16c	17.13b	22.88b	21.05b
SE±	0.59	0.04	0.71	0.62
Significance	**	**	**	**
Interactions				
N X P	NS	NS	NS	**
N X I	**	NS	NS	**
P X I	NS	NS	NS	NS
N X P X I	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

The effect of irrigation interval on number of cloves/bulb was significant throughout the 3 season experiments. In 1994/95 trial, there was significant decrease in number of cloves/bulb with delay in irrigation. In 1995/96 trial and the combined analysis, the 5-day irrigation interval produced significantly more cloves/bulb than 10 and 15-day irrigation interval, which were statistically similar. In 1996/97 study, however, there was no significant difference between 5 and 10-day as well as between 10 and 15-day irrigation intervals in relation to number of cloves/bulb, though 5-day interval had produced significantly more cloves/bulb than 15 days irrigation interval.

There was significant nitrogen x phosphorus interaction on number of cloves/bulb in the combined analysis. There was also significant nitrogen x Irrigation interaction on number of cloves/bulb in 1994/95 trial as well as in the combined analysis (Table 28). The nitrogen x phosphorus interaction on number of cloves/bulb in the combined analysis (Table 28) revealed that irrespective of phosphorus level considered, the number of cloves produced per bulb at all rates of applied nitrogen were statistically similar, though significantly higher than those obtained when no nitrogen was applied. Comparing the various phosphorus levels, while keeping the various rates of nitrogen constant, it

Table 28: Number of cloves/bulb as affected by Nitrogen x Phosphorus and nitrogen x irrigation interval interactions on in the combined analysis and during 1994/95 trial respectively.

	Nitrogen (Kg N/ha)			
Treatments	0	75	150	225
Phosphorus (kgP$_2$O$_5$/ha)		Combined		
0	9.36f	23.41d	24.52cd	26.36cd
75	11.77ef	29.21a	26.94abc	28.39ab
150	12.54e	25.82bcd	26.42abc	28.04ab
SE±	1.056			
Irrigation Interval (day)		1994/95		
5	10.97d	29.70a	28.79ab	29.76a
10	12.62d	23.81c	24.29c	24.60bc
15	10.08d	24.93bc	24.80bc	24.41c
SE±	1.433			
Irrigation Interval (day)		Combined		
5	12.41e	32.36a	31.13ab	31.36ab
10	12.86e	26.47cd	27.58bc	28.98bc
15	11.67e	25.17d	25.79cd	25.01d
SE±	1.087			

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

was observed that the application of 0 and 75kg P_2O_5/ha produced statistically similar number of cloves per bulb with the application of 0 and 150kg N/ha, respectively. However, under 75 and 225kg N/ha, the application of 75kg P_2O_5/ha produced significanlty higher number of cloves per bulb than 0kg P_2O_5/ha, respectively. The application of 75kg P_2O_5/ha in combination with 75kg N/ha produced number of cloves per bulb that was statistically comparable with what was produced with the application of 150kg P_2O_5/ha in combination with higher rates of N.

The nitrogen x irrigation interval interaction on number of cloves per bulb that was registered in 1994/95 trial (Table 28) revealed that the various rates of applied-N were statistically, superior over the control treatment irrespective of irrigation treatments. However, comparing the irrigation treatments while keeping the nitrogen rates constant, it was observed that the various irrigation treatments were statistically at par under 0kg N/ha. When 75kg N/ha was considered it was noted that the 5-day irrigation interval produced significantly more cloves per bulb than either 10 or 15-day intervals, which were also found to be statistically similar. At 150 and 225kg N/ha, however, the 10 and 15-day irrigation intervals produced statistically similar mean values on number of cloves per bulb.

The nitrogen x irrigation interval interaction on number of cloves per bulb as obtained in the combined analysis (Table 28) revealed that irrespective of irrigation interval used, all rates of applied nitrogen produced statistically similar number of cloves per bulb, though they produced significantly more cloves per bulb than when no nitrogen was applied. Comparing the various irrigation treatments while keeping the nitrogen treatments constant, it was observed that under 0kgN/ha, the various irrigation treatments did not register any significant difference in terms of number of cloves per bulb. However, under 75kg N/ha, the 5-day irrigation interval produced significantly more cloves per bulb than either 10 or 15-day intervals, which were observed to be statistically similar. Under 150kg N/ha however, the 5-day irrigation was superior only to 15-day irrigation interval, while similar statistically to 10-day irrigation interval.

4.2.2 Mean clove weight (gm)

The effect of nitrogen, phosphorus levels and irrigation interval on mean clove weight during 1994/95, 1995/96 and 1996/97 dry seasons as well as in the combined analysis is shown on Table 29.

The application of 75, 150 and 225kg N/ha produced cloves that have similar weights statistically throughout the 3 year experiment as well as in the combined analysis. The control treatment however, produced significantly heavier cloves than all rates of applied-N throughout the 3 seasons and in the combined analysis.

Application of phosphorus produced significant effect on weight of cloves. In the 1994/95 trial, application of 75kg P_2O_5/ha recorded significantly heavier cloves than 0kg P_2O_5/ha, while no significant difference was recorded between 75 and 150kg P_2O_5/ha as well as between 0 and 150kg P_2O_5/ha. In 1995/96 trial and the combined analysis, application of 75kg P_2O_5/ha had recorded statistically heavier cloves than either 0 or 150kg P_2O_5/ha which were statistically at par. In 1996/97 trial, however, significant increase in clove weight was recorded with increased application of P from 0 to 75kg P_2O_5/ha. A further increase beyond 75kg P_2O_5/ha did not increase mean clove weight.

Table 29: Mean clove weight (gm) as affected by varying levels of nitrogen, phosphorus and irrigation intervals during 1994/95,1995/96 and 1996/97 dry seasons at Samaru

Treatment(s)	1994/95	1995/96	1996/97	Combined
Nitrogen (kg N/ha)				
0	1.138a	0.808a	0.992a	0.979a
75	0.543b	0.538b	0.557b	0.546b
150	0.548b	0.500b	0.594b	0.547b
225	0.428b	0.413b	0.433b	0.425b
SE±	0.053	0.078	0.082	0.040
Significance	**	**	**	**
Phosphorus (kg P_2O_5/ha)				
0	0.606b	0.605b	0.622b	0.611b
75	0.786a	0.763a	0.807a	0.785a
150	0.741ab	0.611b	0.692a	0.681b
SE±	0.052	0.035	0.051	0.030
Significance	**	**	**	**
Irrigation Interval (day)				
5	0.762a	0.845a	0.765a	0.791a
10	0.591b	0.590b	0.509b	0.563b
15	0.540b	0.584b	0.531b	0.552b
SE±	0.046	0.068	0.071	0.040
Significance	**	**	**	**
Interactions				
N X P	NS	NS	NS	NS
N X I	NS	NS	NS	NS
P X I	NS	NS	NS	NS
N X P X I	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

Irrigation interval has been observed to have significant influence on clove weight of garlic. Throughout the 3 seasons trial and the combined analysis, the 5-day irrigation interval produced statistically heavier cloves than either 10 or 15-day irrigation intervals, which were observed to be statistically similar in all trials and in the combined studies.

None of the first and second order interactions had significant effect on average clove weight throughout the years and in the combined analysis.

4.2.3 Mean bulb size (cm)

The influence of nitrogen, phosphorus levels and irrigation interval on bulb size during 1994/95, 1995/96 and 1996/97 as well as the combined analysis is presented in Table 30.

The application of 75, 150 and 225kg N/ha produced statistically similar bulb sizes in 1994/95 trial, while the control treatment produced statistically the smallest bulb size. However, in the 1995/96, 1996/97 seasons and in the combined analysis, application of 75kg N/ha produced significantly larger bulb size than all other N-rates. There was, however, no statistical difference between 150 and 225kg N/ha both in the 1995/96 and 1996/97 trials as well as in the combined analysis. The control treatment, however, persistently produced the smallest bulbs statistically in all investigation.

Phosphorus application had produced significant effect on garlic bulb size in all the 3 seasons and the combined analysis. The control treatment produced statistically smaller bulb sizes in all years of experimentation and in the combined analysis, while there was no significant difference between 75 and 150kg P_2O_5/ha throughout the seasons.

Irrigation interval significantly influenced garlic bulb size in the 3 seasons trial. In 1994/95 and 1996/97 trials, irrigating garlic at 5 days interval produced

Table 30: Mean bulb size (cm) as influenced by varying levels of nitrogen, phosphorus and irrigation intervals during 1994/95,1995/96 and 1996/97 dry seasons at Samaru

Treatment(s)	1994/95	1995/96	1996/97	Combined
Nitrogen (kg N/ha)				
0	2.029b	2.260c	2.450c	2.246c
75	3.274a	2.931a	3.171a	3.126a
150	3.281a	2.620b	2.819b	2.906b
225	3.024a	2.567b	2.767b	2.786b
SE±	0.11	0.05	0.08	0.05
Significance	*	**	**	**
Phosphorus (kg P_2O_5/ha)				
0	2.923b	2.468b	2.588b	2.660b
75	3.221a	2.651a	2.854a	2.909a
150	3.313a	2.664a	2.863a	2.947a
SE±	0.08	0.05	0.07	0.04
Significance	*	*	*	*
Irrigation Interval (day)				
5	3.473a	2.825a	3.028a	3.109a
10	3.066b	2.566b	2.784b	2.805b
15	2.917b	2.393c	2.593b	2.634c
SE±	0.10	0.04	0.07	0.04
Significance	*	**	*	**
Interactions				
N X P	NS	NS	NS	NS
N X I	NS	NS	NS	NS
P X I	NS	NS	NS	NS
N X P X I	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

significantly larger bulbs than either 10 or 15-day intervals which were statistically at par. However, in the 1995/96 trials and the combined analysis, the bulb size was observed to significantly decrease with each increase in number of days between irrigations.

None of the interactions had any significant influence on the garlic bulb size in all years of study and in the combined analysis.

4.2.4 Mean bulb weight (gm)

The influence of nitrogen, phosphorus levels and irrigation interval on mean bulb weight during 1994/95, 1995/96 and 1996/97 dry seasons and the combined analysis is indicated on Table 30

Nitrogen application had produced significant effect on bulb weight of garlic. In the 1994/95 and 1996/97 trials as well as in the combined analysis application of 75 and 150kg N/ha produced statistically similar bulb weights, though significantly higher than 0 and 225kg N/ha, which were statistically similar. However, in 1995/96 trial, all rates of applied N resulted in similar bulb weights which were significantly higher than the control treatment.

Phosphorus application has been observed to have significant influence on bulb weight of garlic. Throughout the 3-season trials and in the combined analysis application of 75 and 150kg P_2O_5/ha produced statistically similar bulb weights, though statistically superior over the control treatment.

Irrigation interval also recorded significant effect on bulb weight in all investigations. The 5-day irrigation interval was observed to have produced significantly heavier bulbs than either 10 or 15 days irrigation intervals, the difference of which was not statistically significant.

Table 31: Mean bulb weight (gm) as affected by varying levels of nitrogen, phosphorus and irrigation intervals during 1994/95,1995/96 and 1996/97 dry seasons at Samaru

Treatment(s)	1994/95	1995/96	1996/97	Combined
Nitrogen (kg N/ha)				
0	12.17b	7.83b	11.99b	10.67b
75	15.66a	11.19a	15.76a	14.20a
150	16.06a	10.77a	15.27a	14.02a
225	12.65b	9.36a	12.69b	11.57b
SE±	0.98	0.79	0.67	0.52
Significance	**	*	**	**
Phosphorus (kg P_2O_5/ha)				
0	11.69b	7.94b	11.58b	10.40b
75	14.89a	10.89a	14.86a	13.55a
150	16.55a	11.34a	15.73a	14.54a
SE±	0.85	0.41	0.05	0.36
Significance	**	**	**	**
Irrigation Interval (day)				
5	17.73a	12.47a	17.29a	15.83a
10	13.14b	8.80b	12.58b	11.50b
15	12.26b	8.09b	11.91b	10.70b
SE±	1.02	0.69	0.58	0.45
Significance	**	**	**	**
Interactions				
N X P	NS	NS	**	**
N X I	**	NS	**	**
P X I	NS	NS	NS	NS
N X P X I	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

Significant nitrogen x phosphorus interaction was recorded on bulb weight in 1996/97 and in the combined analysis. There was also significant nitrogen x irrigation interaction on this parameter in all investigations except 1995/96 season (Table 32). The nitrogen x phosphorus interaction on mean bulb weight that was recorded in the 1996/97 trial and in the combined analysis revealed that when phosphorus levels are held constant while comparing the various nitrogen rates, there was a significant increase in bulb weight when nitrogen rate was increased from 0kg N/ha to 75kg N/ha under 0kg P_2O_5/ha. A further increase beyond thi rate, reduced the bulb weight in 1996/97 whereas no sucl significant difference was observed in combined analysis. At 75 and 150kg P_2O_5/ha, all applied nitrogen rates resulted in similar bulb weights though producing significantly heavier bulbs than the control treatment. Comparing the various phosphorus rates while keeping N - rates constant, it was observed that there was a significant increase in bulb weight when phosphorus level was raised from 0 to 75 or 150kg P_2O_5/ha at all rates of applied nitrogen except at 225kg N/ha wherein 150kg P_2O_5/ha produced significantly heavier bulbs than 75kg P_2O_5/ha.

The Nitrogen x irrigation interval interaction on bulb weight in 1994/95,1996/97 and in the combined

Table 32: Mean bulb weight (gm) as affected by Nitrogen x Phosphorus and nitorgen x irrigation interval interactions during 1994/95 and 1996/97 trials as well as combined analysis.

Treatments	Nitrogen (Kg N/ha) 0	75	150	225
Phosphorus (kg P_2O_5/ha)		1996/97		
0	8.07f	12.87cd	11.05ef	10.75ef
75	11.80e	16.82ab	15.83abc	15.41bc
150	12.50de	17.58ab	18.93a	18.90a
SE±	1.058			
Phosphorus (kg P_2O_5/ha)		combined		
0	18.28d	10.92c	10.60cd	9.82cd
75	10.87c	15.35b	14.81b	14.96b
150	11.83c	16.34ab	17.06ab	17.92a
SE±	0.782			
Irrigation Interval (day)		1994/95		
5	14.85c	19.63ab	21.99a	18.45b
10	10.41d	14.09c	13.26cd	10.79d
15	10.26d	13.25cd	12.83cd	12.71cd
SE±	1.04			
Irrigation Interval (day)		1996/97		
5	14.28bc	19.52a	20.98a	18.39a
10	11.18d	14.82b	13.09bcd	11.21d
15	10.52d	12.93bcd	11.73cd	12.46bcd
SE±	0.966			
Irrigation Interval (day)		combined		
5	12.78bc	17.69a	19.44a	17.42a
10	11.35bcd	13.02b	11.53bcd	10.11cd
15	8.86d	11.89bc	11.09bcd	11.17bcd
SE±	0.908			

Means followed by the same letter(s) within a set of interaction are not significantly different at 5% level of Probability using Duncan Multiple Range Test (DMRT).

analysis (Table 32) revealed that when irrigation treatments are held constant while comparing the N-rates, at 5-day irrigation interval significant increase in bulb weight was recorded when nitrogen rate was raised from 0 to 75 or 150kg N/ha; a further increase resulted in significant reduction in 1994/95, while the difference was not significant in 1996/97 and in the combined analysis. At 10 and 15-day intervals, however, all rates of nitrogen produced statistically similar bulb weights except at 10-day interval in 1994/95 and 1996/97 trials where 75kg N/ha was statistically higher than the control.

2.5 Fresh Bulb yield (Kg/ha)

The effect of nitrogen, phosphorus levels and irrigation interval on garlic fresh bulb yield during 1994/95, 1995/96 and 1996/97 dry seasons and combined analysis on fresh bulb yield is presented in Table 33.

Nitrogen application had significantly affected fresh bulb yield of garlic. In all investigations, except in 1995/96 trial, there was no significant difference in fresh bulb yield between all rates of applied nitrogen, though only 75 and 150kg N/ha were statistically superior over the control in 1994/95. In the 1995/96 trial, however, the fresh bulb yield increased significantly with increase in applied N from 0 to 75 or 150kg N/ha; a further increase in applied resulted in significant

reduction compared to 75kg N/ha, while the control treatment produced statistically lower fresh bulb yield/ha.

Phosphorus application has significantly affected fresh bulb yield of garlic. In the 1994/95 trial and the combined analysis, the increase in fresh bulb yield due to increased P application was only significant at 75kg P_2O_5/ha, a further increase beyond 75kg P_2O_5/ha resulted in no significant increase. In 1995/96, there was a progressive increase in fresh bulb yield with increase in applied phosphorus. However, in 1996/97 trial, application of 75kg P_2O_5/ha produced significantly higher fresh bulb yield than 150kg P_2O_5/ha, which in turn was statistically superior to the control treatment.

Irrigation interval was also observed to have influenced fresh bulb yield of garlic. Throughout the 3 season trials, the 5-day irrigation interval produced statistically higher fresh bulb yield than either 10 or 15-day irrigation intervals, respectively, which were also observed to be similar statistically.

Nitrogen x phosphorus interaction was significant on fresh bulb yield in 1996/97 and in the combined analysis. The nitrogen x irrigation interaction was also significant in all investigations except in 1995/96 (Table 33).

Table 33: Fresh bulb yield (Kg/ha) as influenced by varying levels of nitrogen, phosphorus and irrigation intervals during 1994/95,1995/96 and 1996/97 dry seasons at Samaru

Treatment(s)	1994/95	1995/96	1996/97	Combined
Nitrogen (kg N/ha)				
0	7780b	5218c	8660b	7219b
75	10437a	7463a	17505a	11802a
150	10686a	7181ab	14813a	10893a
225	8410ab	6241b	14424a	9692a
SE±	786.7	328.8	1442.7	575.4
Significance	**	**	**	**
Phosphorus (kg P_2O_5/ha)				
0	7778b	5290c	8065c	7044b
75	9925a	6728b	16624a	11093a
150	11031a	7559a	14362b	10984a
SE±	565.9	272.6	615.8	293.2
Significance	**	**	**	**
Irrigation Interval (day)				
5	11819a	8317a	14363a	11500a
10	8741b	5867b	10137b	8248b
15	8174b	5394b	10050b	7873b
SE±	681.3	457.9	1249.4	498.3
Significance	**	**	**	**
Interactions				
N X P	NS	NS	**	**
N X I	**	NS	**	**
P X I	NS	NS	NS	NS
N X P X I	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

The significant nitrogen x phosphorus interaction on fresh bulb yield in 1996/97 trial and in the combined analysis (Table 34) revealed that when nitrogen treatments are compared while keeping phosphorus levels constant, with no phosphorus application the garlic fresh bulb yield was observed to significantly increase when nitrogen was increased from 0 to 75 or 150kg N/ha and further increase to 225kg N/ha did not increase fresh yield 1996/97; while there was a reduction when compared with 75kg N/ha in combined analysis. Similar response was recorded when phosphorus level was raised to either 75 or 150kg P_2O_5/ha. Comparing the various phosphorus rates while keeping the nitrogen treatments constant, it was observed that under all rates of nitrogen, the fresh bulb yield/ha was observed to significantly increase with increase in applied phosphorus but only up to 75kg P_2O_5/ha; a further increase did not increase fresh bulb yield.

The significant nitrogen x irrigation interval interaction on fresh bulb yield in the 1994/95 and 1996/97 experiments and combined analysis (Table 34) has revealed that examining the same rate of nitrogen at varying irrigation treatments, it was noticed that there was a significant reduction in fresh bulb yield as irrigation interval was increased from 5 to 10 days at all rates of applied nitrogen except under 225kg N/ha in

Table 34: Fresh bulb yield (Kg/ha) as affected by Nitrogen x Phosphorus and nitorgen x irrigation interval during 1994/95 and 1996/97 trials and the combined analysis respectively.

Treatments	Nitrogen (Kg N/ha) 0	75	150	225
Phosphorus (kg P_2O_5/ha)		1996/97		
0	4885c	10913b	10447b	11016b
75	11124b	18250a	19662a	17459a
150	10407b	17350a	14893ab	14795ab
SE±	1758			
Phosphorus (kg P_2O_5/ha)		combined		
0	4748g	10055cde	7903ef	7806f
75	8331def	12581ab	12644ab	10814abc
150	8578cdef	12769a	12133abc	10455bcd
SE±	748			
Irrigation Interval (day)		1994/95		
5	9893b	13085a	14663a	9636bc
10	6606ef	9393bc	8840bcde	7124cdef
15	6040f	6833def	6555ef	6470ef
SE±	862			
Irrigation Interval (day)		1996/97		
5	12739de	20456a	20189a	17392ab
10	11007ef	13619cde	16859bc	13772cde
15	9233f	11918def	11639def	14430bcd
SE±	1098			
Irrigation Interval (day)		combined		
5	9258b	14276a	12839a	12102a
10	8751bc	9625b	9590b	8816bc
15	6648c	80276c	8250bc	8633bc
SE±	796			

Means followed by the same letter(s) within a set of interaction are not significantly different at 5% level of Probability using Duncan Multiple Range Test (DMRT).

1994/95 where no statistical difference amongst the two treatments was recorded. There was also no significant difference between 10 and 15-day irrigation intervals at all levels of nitrogen with the exception of 75kg N/ha in 1994/95 and combined analysis where 10-day irrigation interval produced statistically higher fresh bulb yield than 15-day interval. Considering the same irrigation interval while comparing the varying nitrogen rates, it was observed that at 5-day irrigation interval significant increase in fresh bulb yield was recorded when nitrogen rate was increased from 0 to 75kg N/ha and further increase in applied-N beyond 150kg N/ha resulted in a significant yield reduction only in 1994/95. Considering the 10-day irrigation interval, however, it was noticed that the fresh bulb was significantly increased with increase in applied-N up to 75kg N/ha in 1994/95, and 150kg N/ha 1996/97; further increase in nitrogen beyond these rates did not register any significant effect compared to 0Kg N/ha. Under the longest irrigation interval, all nitrogen treatments did not differ significantly in relation to fresh bulb yield, except in 1996/97, where 225kg N/ha was significantly higher than the control treatment (Table 34).

Cured bulb yield (kg/ha)

The effect of nitrogen, phosphorus levels and irrigation interval on cured garlic bulb yield during

1994/95, 1995/96 and 1996/97 dry seasons and in the combined analysis is presented on Table 35.

Nitrogen application has significantly influenced garlic cured bulb yield in all years of study. The initial N-levels of 75 and 150kgN/ha resulted in significantly higher cured bulb yield than the control; and a further increase in N to 225kg/ha has reduced yield at the same level as control in all investigations. However, the difference between 150 and 225kgN/ha was significant in 1996/97 and in the combined analysis.

Phosphorus application produced significant effect on cured bulb yield throughout the study. In 1994/95 and 1996/97 studies and in the combined analysis, 75 and 150kgP_2O_5/ha produced statistically similar cured bulb yield, while the control treatment statistically produced the lowest cured bulb yield. In 1995/96 trial, however, there was a progressive increase in cured bulb yield with each increase in applied phosphorus.

Irrigation interval was also observed to have affected cured bulb yield of garlic. Throughout the 3 season experiments and the combined analysis, the use of 5-days irrigation interval produced significantly higher cured bulb yield than either 10 or 15 days irrigation interval, which were observed to be statistically at par throughout the studies. Nitrogen x phosphorus interaction was significant on cured bulb yield in all

Table 35: Cured Bulb yield (Kg/ha) as influenced by varying levels of nitrogen, phosphorus and irrigation intervals during 1994/95,1995/96 and 1996/97 dry seasons at Samaru

Treatment(s)	1994/95	1995/96	1996/97	Combined
Nitrogen (kg N/ha)				
0	7485.0b	4959.0b	7993.0b	6812b
75	10076.0a	6863.0a	10204.0a	9047a
150	10419.0a	6980.0a	10291.0a	9230a
225	8472.0ab	5952.0ab	8558.0b	7660b
SE±	736.5	529.5	448.1	337.2
Significance	**	**	**	**
Phosphorus (kg P_2O_5/ha)				
0	7381.0b	4998.0c	7733.0b	6700b
75	9457.0a	6431.0b	9652.0a	8514a
150	10388.0a	7258.0a	10486.0a	9377a
SE±	518.2	270.6	333.6	294.4
Significance	**	**	**	**
Irrigation Interval (day)				
5	11140.0a	8016.0a	11538.0a	10231a
10	8122.0b	5567.0b	8382.0b	7357b
15	7965.0b	5105.0b	7939.0b	7003b
SE±	637.9	458.6	388.1	292.0
Significance	**	**	**	**
Interactions				
N X P	NS	**	**	**
N X I	**	**	**	**
P X I	NS	NS	NS	NS
N X P X I	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

investigations except in 1994/95 season (Table 35). Nitrogen x Irrigation interaction was also found to be highly significant on cured bulb yield in all investigation (Table 35).

The Nitrogen x phosphorus interaction on cured bulb yield in 1995/96, 1996/97 and in the combined analysis as contained in Table 36 revealed that under no phosphorus application, there was a significant increase in cured bulb yield with increase in applied -N upto 75kg N/ha, a further increase to 150kg N/ha did not have significant effect. Similar trend was recorded at 75 and 150kg P_2O_5/ha though no significant difference between 225kg N/ha and the control was recorded. Comparing the various phosphorus rates under same nitrogen treatment, it was noted that at 0, 75 and 225kg N/ha, the application of 75 and 150kg P_2O_5/ha produced statistically similar cured bulb yield in all interactions (Table 36). Under 150kg N/ha, it was observed that the cured bulb yield was significantly increased with increasing rate of applied phosphorus in 1995/96, 1996/97 and the combined analysis.

The significant nitrogen x irrigation interval interaction on cured bulb yield (Table 37) in all investigations revealed that under 5-day irrigation interval, cured bulb yield increased significantly with increase in applied nitrogen from 0 to 75kg N/ha, while further increase to 225kg N/ha resulted in significant

Table 36: Cured bulb yield (Kg/ha) as affected by Nitrogen x Phosphorus interaction during 1994/95 and 1996/97 trials and the combined analysis respectively.

Treatments	Nitrogen (Kg N/ha) 0	75	150	225
Phosphorus (kg P_2O_5/ha)		1995/96		
0	3526f	4994e	5372de	5991cde
75	4774ef	7913ab	6900bc	6138bcde
150	5265de	8676a	8368a	6728bcd
SE±	489			
Phosphorus (kg P_2O_5/ha)		1996/97		
0	3777f	8579de	7367e	7164e
75	7868de	11213ab	10587bc	8941d
150	8333de	11721ab	12619a	9269cd
SE±	505			
Phosphorus (Kg P_2O_5/ha)		combined		
0	4400f	7117de	6896e	6396e
75	6783e	10041ab	9427bc	7803de
150	7217de	10692ab	11167a	8433cd
SE±	497			

Means followed by the same letter(s) within a set of interaction are not significantly different at 5% level of Probability using Duncan Multiple Range Test (DMRT).

Table 37: Cured bulb yield (Kg/ha) as affected by Nitrogen x Irrigation interaction during 1994/95 and 1996/97 trials and the combined analysis respectively.

Treatments	Nitrogen (KgN/ha) 0	75	150	225
Irrigation Interval (day)		1994/95		
5	8109bc	12757a	14296a	9895b
10	7899bc	8159bc	8619bc	7013d
15	5047d	8612bc	8341bc	6259cd
SE±	875			
Irrigation Interval (day)		1995/96		
5	3342e	8987a	9935a	8301ab
10	3341e	6473bc	5201cde	5253cde
15	3583de	6030c	5504cd	5303cde
SE±	717			
Irrigation Interval (day)		1996/97		
5	9520bc	13012a	14026a	13595a
10	7448cd	9880b	8726bcd	7476cd
15	7010d	8622bcd	7822bcd	8304bcd
SE±	776			
Irrigation Interval (day)		combined		
5	6990cd	11580ab	12752a	10597b
10	6163de	8171c	7515cd	6580cde
15	5213e	7754cd	7222cd	6622cde
SE±	584			

Means followed by the same letter(s) within a set of interaction are not significantly different at 5% level of Probability using Duncan Multiple Range Test (DMRT).

yield reduction only in 1994/95 and no significant increase in 1995/96, 1996/97 and the combined analysis. Under the 10 days irrigation interval, however, no significant effect was recorded on cured bulb yield as a result of applying varying levels of nitrogen from 0 to 150kg N/ha in 1994/95 season. When 15-day irrigation interval was considered, it was evident that a signigicant increase in cured bulb yield was recorded when applied nitrogen was increased from 0 to 75kg N/ha except in 1996/97 trial; a further increase did not produce appreciable increase in all investigation. Comparing the various irrigation treatments while keeping the nitrogen levels constant, it was observed that the 5-day irrigation interval produced significantly higher cured bulb yield than 10 and 15-day irrigation intervals, respectively under all rates of applied nitrogen, except under the control where 5 and 10-day irrigation intervals were statistically at par in all investigations (Table 37). It was also observed that the 10 and 15-day irrigation intervals produced cured bulb yields that were statistcally similar under all rates of applied nitrogen except under 0kg N/ha in 1994/95, where 10-day interval was statistically superior over 15-day irrigation interval.

4.2.7 Bulb crude protein content (gm/100g sample)

The effect of nitrogen, phosphorus levels and irrigation interval on bulb crude protein content during 1994/95 1995/96 and 1996/97 dry season and combined analysis is shown on Table 38.

The effect of applied-N on bulb crude protein content was significant throughout the 3 seasons study and in the combined analysis. The bulb crude protein content was observed to significantly increase with increase in applied nitrogen upto 225kg N/ha. This trend was noted throughout the study and in the combined analysis.

Phosphorus application was also noted to have significant influence on garlic bulb protein content. The protein content was observed to significantly increase with increase in applied phosphorus from 0 to 75kg P_2O_5/ha, a further increase to 150kg P_2O_5/ha did not increase crude protein content although difference between these rates was not significant. This trend was recorded in all years of study and in the combined analysis.

Irrigation interval has been noted to influence crude protein content of garlic bulbs. There was a significant decreasing trend in protein content of bulbs with increase in days between irrigation. This trend was obtained in all years of study as well as in the combined analysis.

Table 38: Bulb crude protein content (gm/100gm sample) as influenced by varying levels of nitrogen, phosphorus and irrigation intervals during 1994/95,1995/96 and 1996/97 dry seasons at Samaru

Treatment(s)	1994/95	1995/96	1996/97	Combined
Nitrogen (kg N/ha)				
0	3.479d	3.075d	3.304d	3.286d
75	5.178c	4.914c	5.058c	5.050c
150	5.595b	5.288b	5.457b	5.447b
225	6.413a	6.089a	6.229a	6.244a
SE±	0.100	0.103	0.096	0.06
Significance	**	**	**	**
Phosphorus (kg P_2O_5/ha)				
0	4.579b	4.247b	4.423b	4.416b
75	5.455a	5.153a	5.310a	5.306a
150	5.464a	5.126a	5.302a	5.297a
SE±	0.080	0.092	0.084	0.05
Significance	**	**	**	**
Irrigation Interval (day)				
5	5.603a	5.311a	5.440a	5.451a
10	5.313b	4.956b	5.157b	5.142b
15	4.582c	4.259c	4.438c	4.426c
SE±	0.081	0.089	0.083	0.05
Significance	**	**	**	**
Interactions				
N X P	NS	**	**	**
N X I	**	**	**	**
P X I	**	**	**	**
N X P X I	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

All first order interactions were found to be highly significant, except N x P in 1994/95 dry season.

The *nitrogen x phosphorus interaction* on bulb crude protein content in 1995/96, 1996/97 and in the combined analysis (Table 39) revealed that the bulb crude protein content significantly increased with increase in applied nitrogen upto 225kg N/ha; this increase was recorded under all levels of phosphorus. Comparing the various phosphorus levels under same level of nitrogen, it was observed that under all levels of nitrogen, the application of 75 and 150kg P_2O_5/ha produced statistically similar bulb crude protein content except in the combined analysis, while the application of 0kg P_2O_5/ha produced statistically lower crude protein contents irrespective of nitrogen level applied. Generally, the application of 225kg N/ha had consistently produced statistically higher bulb crude protein content than any nitrogen rate under all levels of applied phosphorus.

The nitrogen x irrigation interval interaction on bulb crude protein content throughout the investigations (Table 40) revealed that all rates of applied nitrogen produced statistically similar bulb crude protein content under 5 days irrigation interval except in the combined analysis while 225kg N/ha was superior to 75kg N/ha. The the combination of 0kg N/ha with 5-day irrigation

Table 39: Bulb crude protein content (gm/100 gm sample) as affected by Nitrogen x Phosphorus interaction during 1995/96 and 1996/97 as well as in the combined analysis respectively.

Treatments	Nitrogen (Kg N/ha) 0	75	150	225
Phosphorus (kg P_2O_5/ha)		1995/96		
0	2.382g	4.546e	4.661de	5.398bc
75	3.203f	5.166cd	5.730b	6.512a
150	3.640f	5.032cde	5.472bc	6.358a
SE±	0.182			
Phosphorus (kg P_2O_5/ha)		1996/97		
0	2.759h	4.656f	4.771ef	5.508bc
75	3.413g	5.276cd	5.840b	6.711a
150	3.739g	5.242de	5.760bc	6.468a
SE±	0.169			
Phosphorus (kg P_2O_5/ha)		combined		
0	2.678i	4.660f	4.776f	5.551cd
75	3.407h	5.279de	5.850b	6.688a
150	3.773g	5.211e	5.714bc	6.491a
SE±	0.099			

Means followed by the same letter(s) within a set of interaction are not significantly different at 5% level of Probability using Duncan Multiple Range Test (DMRT).

interval produced statistically lower crude protein content. Considering 10-day irrigation interval, it was observed that similar trend as that under 5-day irrigation interval was recorded in 1994/95 and 1996/97 seasons. In 1995/96 increase in bulb crude protein content was significant upto 150kg N/ha, while it was upto 225kg N/ha in the combined analysis. At 15-day irrigation interval, the bulb crude protein content significantly increase with increase in applied N upto 225kg N/ha in all investigations. Comparing the various irrigation treatments while keeping nitrogen rates constant it was observed that under 75 and 150kg N/ha, there was a significant decrease in bulb crude protein content as irrigation interval was increased from 5 to 15 days. Under 0kg N/ha, however, no statistical difference was recorded between 5 and 10-day intervals in all investigations except in the combined analysis. Under the highest rate of applied nitrogen (225kg N/ha), however, significant decrease in bulb crude protein content was recorded only when irrigation interval was increased from 5 to 10-day between irrigations; while no statistical difference was recorded between 10 and 15-day irrigation intervals in all investigations.

The phosphorus x irrigation interval interaction on bulb crude protein content in all investigations (Table 41) revealed that under the 5-day irrigation interval,

Table 40: Bulb crude protein content (gm/100gm sample) as affected by Nitrogen x Phosphorus interaction during 1994/95, 1995/96 and 1996/97 as well as in the combined analysis respectively.

Treatments	Nitrogen (Kg N/ha) 0	75	150	225
Irrigation Interval (day)		1994/95		
5	3.847f	5.971ab	6.117a	6.479a
10	3.581f	5.176c	5.014cd	5.473bc
15	3.001g	4.447e	4.593de	5.286c
SE±	0.174			
Irrigation Interval (day)		1995/96		
5	3.559de	5.661a	5.919a	6.103a
10	3.123e	3.848cd	5.071b	5.108b
15	2.543f	3.234e	4.273c	4.984b
SE±	0.178			
Irrigation Interval (day)		1996/97		
5	3.658ef	5.771ab	6.029a	6.302a
10	3.411fg	5.058c	4.870cd	5.290bc
15	2.842g	3.344fg	4.272de	5.094bc
SE±	0.234			
Irrigation Interval (day)		combined		
5	3.688g	5.801b	6.022ab	6.295a
10	3.372h	4.694e	4.985de	5.290c
15	2.796i	3.672g	4.379f	5.121cd
SE±	0.100			

Means followed by the same letter(s) within a set of interaction are not significantly different at 5% level of Probability using Duncan Multiple Range Test (DMRT).

Table 41: Bulb crude protein content (gm/100gm sample) as affected by Phosphorus x irrigation interval interaction during 1994/95, 1995/96 and 1996/97 as well as in the combined analysis respectively.

Treatments	Phosphorus (kg P_2O_5/ha) 0	75	150
Irrigation Interval (day)		1994/95	
5	4.959c	6.122a	6.229a
10	4.459d	5.555b	5.435b
15	4.328d	4.688cd	4.729cd
SE±	0.142		
Irrigation Interval (day)		1995/96	
5	4.805cd	5.823a	5.953a
10	4.142e	5.286b	5.036bc
15	4.043e	4.349de	4.384de
SE±	0.157		
Irrigation Interval (day)		1996/97	
5	4.265c	6.000a	6.055a
10	4.785c	5.396b	5.291b
15	4.220c	4.534c	4.561c
SE±	0.144		
Irrigation Interval (day)		combined	
5	4.676c	5.982a	6.079a
10	4.453cd	5.414b	5.254b
15	4.197d	4.524c	4.558c
SE±	0.086		

Means followed by the same letter(s) within a set of interaction are not significantly different at 5% level of Probability using Duncan Multiple Range Test (DMRT).

significant increase in crude protein content of the bulbs was recorded when applied phosphorus level was raised from 0 to 75kg P_2O_5/ha, while a further increase beyond this level did not increase bulb crude protein. Similar trend as obtained under 10-day irrigation interval in all cases. Under the 15-day irrigation interval, however, no statistical difference was recorded between all rates of phosphorus under study including control. Comparing the various irrigation treatments under same phosphorus level, it was observed that under 0kg P_2O_5/ha, the crude protein content was noted to significantly decrease with increase in number of days between irrigations from 5 to 15-day interval in all cases except in 1996/97 wherein there was no significant difference recorded. Under same phosphorus level (0kg P_2O_5/ha) no significant difference in bulb crude protein content was recorded when irrigation interval was increased from 10 to 15-day. However, under 75 and 150kg P_2O_5/ha, the crude protein content of the bulbs decreased progressively with each increase in number of days between irrigations.

.2.8 Bulb phosphorus content (gm/100gm sample)

The effect of nitrogen, phosphorus levels and irrigation interval on bulb phosphorus content during 1994/95, 1995/96 and 1996/97 dry seasons as well as the combined analysis is presented in Table 42.

Nitrogen application has produced significant influence on the bulb phosphorus content in garlic. Throughout the 3-seasons study, increased nitrogen application from 0 to 75kg N/ha produced significant increase in phosphorus content of the bulb. Further increase in applied N produced no significant effect. This trend was recorded in all seasons of study as well as the combined analysis.

Phosphorus application also produced significant effect on bulb phosphorus content. Significant increase in bulb phosphorus content was recorded with the initial increase in P from 0 to 75kg P_2O_5/ha in all investigations. A further increase from 75 to 150kg P_2O_5/ha, however, did not increase bulb phosphorus content in all investigations.

The 5-day irrigation interval produced statistically higher bulb phosphorus content than either 10 or 15-day irrigation intervals, which were statistically similar. This observation was recorded in all the seasons as well as in the combined analysis.

Nitrogen x phosphorus interaction was significant on bulb phosphorus content in all investigations except 1994/95 season (Table 42). Nitrogen x irrigation interaction was not significant in all investigations except in the combined analysis (Table 42); while the phosphorus x irrigation interaction was highly

Table 42: Bulb phosphorus content (gm/100gm sample) as affected by varying levels of nitrogen, phosphorus and irrigation intervals during 1994/95,1995/96 and 1996/97 dry seasons at Samaru

Treatment(s)	1994/95	1995/96	1996/97	Combined
Nitrogen (kg N/ha)				
0	0.3207b	0.3926b	0.4048b	0.3727b
75	0.4100a	0.4926a	0.5100a	0.4709a
150	0.4339a	0.5248a	0.5356a	0.4998a
225	0.4530a	0.5267a	0.5407a	0.5068a
SE±	0.023	0.020	0.023	0.013
Significance	**	**	**	**
Phosphorus (kg P_2O_5/ha)				
0	0.2189b	0.2964b	0.3033b	0.2729b
75	0.4964a	0.5731a	0.5911a	0.5533a
150	0.5017a	0.5831a	0.5989a	0.5612a
SE±	0.017	0.015	0.016	0.009
Significance	**	**	**	**
Irrigation Interval (day)				
5	0.4681a	0.5456a	0.5553a	0.5230a
10	0.3892b	0.4656b	0.4836b	0.4461b
15	0.3597b	0.4414b	0.4544b	0.4185b
SE±	0.020	0.017	0.020	0.011
Significance	**	**	**	**
Interactions				
N X P	NS	**	**	**
N X I	NS	NS	NS	**
P X I	**	**	**	**
N X P X I	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using Duncan Multiple Range Test (DMRT).

significant in all investigations (Table 42).

The nitrogen x phosphorus interaction on bulb phosphorus content in 1995/96, 1996/97 and in the combined analysis (Table 43) indicated that all the nitrogen rates tested did not influence bulb phosphorus content when no phosphorus fertilizer was applied to the crop except in the combined analysis where 150kg N/ha was superior over control. However, with application of 75kg P_2O_5/ha it was observed that a significant increase in bulb phosphorus content was registered when nitrogen rate was increased from 0 to 75kg N/ha; further increase beyond this rate did not produce any significant increase in bulb phosphorus content except in the combined analysis. Similar trend was recorded under 150kg P_2O_5/ha though in the combined analysis 225kg N/ha produced higher bulb P content than all N rates. Comparing the various phosphorus levels under same nitrogen rate, it was observed that irrespective of nitrogen rate applied, a significant and positive increase in bulb phosphorus content was recorded when phosphorus level was increased from 0 to 75kg P_2O_5/ha in all investigations; further increase to 150kg P_2O_5/ha produced statistically similar phosphorus content as that recorded under 75kg P_2O_5/ha, except in the combined analysis, where 75kg P_2O_5/ha was statistically higher than 150kg P_2O_5/ha under 150kg N/ha.

Table 43: Bulb phosphorus content (gm/100gm sample) as affected by Nitrogen x Phosphorus interaction during 1995/96 and 1996/97 as well as in the combined analysis respectively.

Treatments	Nitrogen (Kg N/ha) 0	75	150	225
Phosphorus (kg P_2O_5/ha)		1995/96		
0	0.2544d	0.3122d	0.3333d	0.2856d
75	0.4489c	0.5700b	0.6500ab	0.6233ab
150	0.4744c	0.5956ab	0.5911ab	0.6711a
SE±	0.031			
Phosphorus (kg P_2O_5/ha)		1996/97		
0	0.2533d	0.3200d	0.3389d	0.3011d
75	0.4733c	0.5867ab	0.6678a	0.6367a
150	0.4878bc	0.6233a	0.6000a	0.6844a
SE±	0.035			
Phosphorus (kg P_2O_5/ha)		combined		
0	0.2326f	0.2841ef	0.3037e	0.2711ef
75	0.4319d	0.5478c	0.6319ab	0.6026ab
150	0.4537d	0.5807bc	0.5637c	0.6467a
SE±	0.0197			

Means followed by the same letter(s) within a set of interaction are not significantly different at 5% level of Probability using Duncan Multiple Range Test (DMRT).

The only nitrogen x irrigation interval interaction on bulb phosphorus content was recorded from the combined analysis (Table 43). From the results, it was observed that irrespective of irrigation treatment considered, the increased application of nitrogen from 0 to 75kg N/ha produced significant increase in the bulb phosphorus content. Further increase in applied nitrogen beyond 75kg N/ha produced no significant increase on bulb phosphorus content except under 15 days irrigation interval where increase of N from 150 to 225kg/ha resulted in a significant reduction in the bulb phosphorus content. Comparing the various irrigation treatments under same nitrogen level, it was observed that under all rates of applied nitrogen the bulb phosphorus content was significantly decreased when irrigation interval was increased from 5 to 10-day, while further increase in days between irrigation did not affect further, the bulb phosphorus content, except under 225kg N/ha, where the bulb phosphorus content was significantly decreased. When no nitrogen was applied, however, the 5, 10 and 15-day irrigation frequencies produced statistically similar bulb phosphorus content (Table 44).

The significant phosphorus x irrigation interval interaction on bulb phosphorus content throughout the 3 season trial (Table 45) and as in the combined analysis, revealed that under each irrigation treatment, a

Table 44: Bulb phosphorus content (gm/100gm sample) nitrogen x irrigation interval interaction as obtained in the combined analysis.

Treatments	Nitrogen (Kg N/ha) 0	75	150	225
Irrigation Interval (day)				
5	0.4093bcde	0.5674a	0.5541a	0.5611a
10	0.3652def	0.4585bc	0.4360bc	0.4507bc
15	0.3300ef	0.3967cd	0.4352bc	0.3085f
SE±	0.022			

Means followed by the same letter(s) within a set of interaction are not significantly different at 5% level of Probability using Duncan Multiple Range Test (DMRT).

Table 45: Bulb phosphorus content (gm/100gm sample) as affected by Phosphorus x irrigation interval interaction during 1994/95, 1995/96 and 1996/97 as well as in the combined analysis respectively.

Treatments	Phosphorus (kg P_2O_5/ha) 0	75	150
Irrigation Interval (day)		1994/95	
5	0.2200c	0.5950a	0.5892a
10	0.2442c	0.4650b	0.4583b
15	0.1925c	0.4292b	0.4575b
SE±	0.031		
Irrigation Interval (day)		1995/96	
5	0.2833c	0.6758a	0.6775a
10	0.3275c	0.5408b	0.5283b
15	0.2783c	0.5025b	0.5433b
SE±	0.027		
Irrigation Interval (day)		1996/97	
5	0.2900c	0.6867a	0.6892a
10	0.3358c	0.5650b	0.5500b
15	0.2842c	0.5217b	0.5575b
SE±	0.030		
Irrigation Interval (day)		combined	
5	0.2644c	0.6525a	0.6519a
10	0.3025c	0.5236b	0.5122b
15	0.2517c	0.4844b	0.5194b
SE±	0.017		

Means followed by the same letter(s) within a set of interaction are not significantly different at 5% level of Probability using Duncan Multiple Range Test (DMRT).

significant increase in bulb phosphorus content was recorded as a result of increased application of phoshorus level from 0 to 75kg P_2O_5/ha, and further increase beyond this level did not increase bulb phosphorus content. This trend was recorded in each season and in the combined analysis. Comparing the various irrigation treatments under same phosphorus level, it was observed that under 0kg P_2O_5/ha, bulb phosphorus contents produced under the various irrigation treatments were statistically similar in all investigations. However, with the application of either 75 or 150kg P_2O_5/ha, it was observed that the 5-day irrigation interval had produced significanly higher bulb phosphorus content than either 10 or 15-day irrigation intervals, which were however, observed to be statistically similar in all cases (Table 45).

Simple correlation studies

The simple correlation matrix between cured bulb yield, growth and other yield components during 3-years investigation were presented in Tables 46,47 and 48 for 1994/95, 1995/96 and 1996/97 dry seasons, respectively.

All characters studied were found to be highly significantly correlated with bulb yield in all investigations, except average number of leaves/plant and average clove weight in 1995/96 trial, where no significant correlation was recorded. It was also noted

that the number of days to maturity in 1994/95 trial was negatively correlated with bulb yield at 1% level of probability. When the associations between plant height and other characters were examined, it was observed that such association was significant on all characters except mean number of cloves/bulb, days to maturity, bulb phosphorus and protein contents in 1994/95 trial, while in 1995/96 the association was weak though positive on mean leaf number per plant, bulb size, clove weight, days to maturity and bulb protein content. In 1996/97 trials, however, plant height was highly correlated with all parameters except average number of leaves/plant and crop growth rate, whose correlation was significant at 5% level of probability; while relative growth rate recorded no significant association with plant height (Table 48). In 1994/95 trial, number of leaves/plant recorded highly significant correlations with all parameters except number of cloves/bulb, clove weight, bulb protein and phosphorus content, where the association was significant at 5% level of probability. In 1995/96 trial, however all associations between leaf number/plant and other characters were highly significant (P=0.01) except with bulb weight, number of cloves/bulb, clove weight, CGR and RGR, where a weak but positive associations were observed (Table 47). The 1996/97 results recorded highly significant correlations between average number of

leaves/plant and all parameters, except bulb weight and clove weight, where no significant associations were established.

Dry matter production/plant had recorded highly significant correlations with all characters with the exception of average clove weight in all investigations. When the correlations between bulb weighht and other characters were observed across the 3-seasons, it was observed that all associations with all characters were significant and positive in all seasons except in 1995/96 where weak and negative association was recorded on average clove weight (Table 47). The association between bulb weight and days to mturity was highly significant in all seasons, though negatively in 1994/95 season. The average bulb size in 1994/95 trial recorded significant correlation (P=0.01) with all parameters except with number of cloves/bulb and bulb protein content where the asssociation was recorded only at 5% level of probability. In the other two seasons, (1995/96 and 1996/97) however, all associations between bulb size and other parameters were highly significant except with clove weight and relative growth rate where weak but positive associations were recorded, respectively.

The relationships between number of cloves/bulb and other parameters in 1994/95 and 1996/97 trials, were highly significant; though the associations were negative

with average clove weight and days to maturity in 1994/95 season. In 1995/96 trial, however, all associations were highly (P=0.01) significant except with relative growth rate where weak but positive association was established. Average clove weight recorded no significant correlations with other characters except bulb crude protein content, where highly significant correlation was recorded. This was recorded in all seasons (Tables 46, 47 and 48, respectively). Average number of days to maturity recorded positive and significant correlation with CGR, bulb protein and phosphorus contents while its association with RGR was not significant though positive in all investigations. Crop growth rate, relative growth rate, bulb protein and phosphorus contents recorded highly significant association in all investigations, except in 1995/96 and 1996/97 where the associations between RGR and bulb protein content were not significant though positive in nature (Table 47 and 48).

Table 46: Simple correlation matrix involving cured bulb yield (kg/ha), growth and yield parameters of garlic during 1994/95 dry season at Samar

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. BY	1.0000												
2. PH	0.4303**	1.0000											
3. LN	0.4904**	0.4487**	1.0000										
4. DM	0.5419**	0.3491**	0.6755**	1.0000									
5. BWt	0.9702**	0.4739**	0.5378**	0.5268**	1.0000								
6. BS	0.9317**	0.4691**	0.5348**	0.5366**	0.9611**	1.0000							
7. C/B	0.3463**	0.1078NS	0.2201*	0.3509**	0.2384*	0.2477*	1.0000						
8. CWt	0.3182**	0.2313*	0.2363*	0.0915NS	0.4765**	0.4581**	-0.6569**	1.0000					
9. DMat	-0.3046**	0.1262NS	0.2675**	-0.3028**	-0.2918**	-0.3055**	-0.4168**	0.0547NS	1.0000				
10. CGR	0.4655**	0.2784**	0.6303**	0.9403**	0.4537**	0.4511**	0.2872**	0.0917NS	0.2041*	1.0000			
11. RGR	0.4015**	0.2353*	0.5091**	0.8496**	0.3983**	0.3943**	0.2366*	0.1040NS	0.1255NS	0.9588**	1.0000		
12. CP	0.2869**	0.0473NS	0.2352*	0.3042**	0.2111*	0.2048*	0.7609**	0.4671**	0.5190**	0.2674**	0.1977*	1.0000	
13 P cont.	0.4610**	0.1558NS	0.3836**	0.4331**	0.4457**	0.4194**	0.4012**	0.0027NS	0.4199**	0.3583**	0.3059**	0.54	1.0000

* - Significant at 5% level of probability
** - Significant at 1% level of probability
NS - Not significant

r - value at 5% = 0.195 at 106 DF.
at 1% = 0.254 at 106 DF.

Key

BY - Cured bulb yield
PH - Plant height
LN - Average leaves No/Plant
DM - Dry matter/plant
DMat- Days to maturity
RGR - Relative growth rate
P cont - bulb phosphorus content.

BWt - Bulb weight
BS - Bulb size
C/B - No of cloves/bulb
CWt - Clove weight
CGR - Crop growth rate
CP - Crude protein content

Table 47: Simple correlation matrix involving cured bulb yield (kg/ha), growth and yield parameters of garlic during 1995/96 dry season at Samaru

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. BY	1.0000												
2. PH	0.5562**	1.0000											
3. LN	0.1670NS	0.1833NS	1.0000										
4. DM	0.5846**	0.3846**	0.0595**	1.0000									
5. BWt	0.9999**	0.5578**	0.1695NS	0.5840**	1.0000								
6. BS	0.4377**	0.1737NS	0.3395**	0.3353**	0.4374**	1.0000							
7. C/B	0.6683**	0.4174**	0.1127NS	0.3911**	0.6671**	0.2793**	1.0000						
8. CWt	-0.0842NS	0.0407NS	0.0424NS	-0.1011NS	0.0826NS	0.1233NS	0.6473**	1.0000					
9. DMat	0.3250**	0.1502NS	0.3732**	0.3231**	0.3261**	0.4683**	0.3081**	0.1589NS	1.0000				
10. CGR	0.4876**	0.3223**	0.0032NS	0.9285**	0.4862**	0.2101*	0.3344**	0.0757NS	0.2107*	1.0000			
11. RGR	0.3020**	0.2190*	0.0143NS	0.5482**	0.3040**	0.0709NS	0.1259NS	0.0964NS	0.1347NS	0.6453**	1.0000		
12. CP	0.3647**	0.0811NS	0.3715**	0.3123**	0.3640**	0.4616**	0.5245**	0.4901**	0.5539**	0.2433*	0.0690NS	1.0000	
13. P cont.	0.4872**	0.2312*	0.2513*	0.4485**	0.4885**	0.3470**	0.3367**	0.1277NS	0.4455**	0.3749**	0.2553**	0.5608**	1.0000

* - Significant at 5% level of probability
** - Significant at 1% level of probability
NS - Not significant

r - value at 5% = 0.195 at 106 DF.
at 1% = 0.254 at 106 DF

Key

BY - Cured bulb yield
PH - Plant height
LN - Average leaves No/Plant
DM - Dry matter/plant
DMat - Days to maturity
RGR - Relative growth rate
P cont - bulb phosphorus content.

BWt - Bulb weight
BS - Bulb size
C/B - No of cloves/bulb
CWt - Clove weight
CGR - Crop growth rate
CP - Crude protein content

Table 48: Simple correlation matrix involving cured bulb yield (kg/ha), growth and yield parameters of garlic during 1996/97 dry season at Samaru

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. BY	1.0000												
2. PH	0.4181**	1.0000											
3. LN	0.4190**	0.2449*	1.0000										
4. DM	0.4260**	0.2797**	0.6001**	1.0000									
5. BWt	0.9999**	0.4182**	0.4178NS	0.4236**	1.0000								
6. BS	0.4409**	0.3168**	0.2737**	0.3562**	0.4404**	1.0000							
7. C/B	0.3233**	0.3389**	0.3360**	0.3561**	0.3231**	0.3928**	1.0000						
8. CWt	0.2677**	0.0409**	0.0753NS	0.0914NS	0.2682**	0.1282NS	0.6695**	1.0000					
9. DMat	0.3938**	0.3247**	0.2542**	0.3503**	0.3930**	0.4409**	0.4036**	0.0872NS	1.0000				
10. CGR	0.3232**	0.2064*	0.5403**	0.9388**	0.3211**	0.2580**	0.2794**	0.0624NS	0.2766**	1.0000			
11. RGR	0.2115*	0.1269NS	0.4816**	0.8065**	0.2105*	0.1703NS	0.2190*	0.0418NS	0.1761NS	0.9370**	1.0000		
12. CP	0.3629**	0.3134**	0.2813**	0.3119**	0.3624**	0.4278**	0.7719**	0.4804**	0.5051**	0.2558**	0.1704NS	1.0000	
13 P cont.	0.4859**	0.2907**	0.4397**	0.4031**	0.4857**	0.3425**	0.4127**	0.0673NS	0.4157**	0.3290**	0.2779**	0.5707**	1.0000

* - Significant at 5% level of probability
** - Significant at 1% level of probability
NS - Not significant

r - value at 5% = 0.195 at 106 DF.
at 1% = 0.254 at 106 DF.

Key

BY - Cured bulb yield
PH - Plant height
LN - Average leaves No/Plant
DM - Dry matter/plant
DMat- Days to maturity
RGR - Relative growth rate
P cont - bulb phosphorus content.
BWt - Bulb weight
BS - Bulb size
C/B - No of cloves/bulb
CWt - Clove weight
CGR - Crop growth rate
CP - Crude protein content

.3.1. Path - Coefficient Analysis

A study of direct and indirect effects of different growth characters on bulb yield in 3 seasons is shown on Tables 49, 50 and 51. The total correlation between plant height and bulb yield varied from 0.418 (1996/97) to 0.556 (1995/96). Out of this, the direct contribution was found to be 0.219, 0.365 and 0.274 in 1994/95, 1995/96 and 1996/97 seasons respectively. The contribution of plant height indirectly via number of leaves/plant was vary small and varied from 0.01 to 0.07. While the contribution of plant height via dry matter/plant was observed to be the highest and varied from 0.142 to 0.276 throughout the 3 seasons. When indirect contribution of plant height via CGR was examined it was negative in all the 3 seasons and varied from -0.019 to -0.141. The plant height contribution via RGR was positive during the 2 seasons and negative in the last season (1996/97) which varied from 0.008 to -0.032.

When the direct and indirect contribution of number of leaves/plant to bulb yield was critically examined, it was observed that its direct contributions to bulb yield were 0.158, 0.057 and 0.218 for 1994/95, 1995/96 and 1996/97 out of total correlations of 0.4904, 0.167 and 0.419 respectively. Its indirect contributions via plant height varied from 0.067 to 0.092. The indirect contribution of number of leaves/plant via dry matter

production/plant was highest in all seasons and ranged from 0.0424 in 1995/96 to 0.4696 in 1994/95. The contributions of number of leaves/plant via CGR were negative in two seasons (1994/95 and 1996/97) and positive in 1995/96 and varied from -0.3192 to 0.001. Similarly, indirect contributions of leaf number/plant via RGR were negative in the last two seasons (1995/96 and 1996/97) but positive in the first season and varied from -0.1210 to 0.0838.

When the direct and indirect contributions of dry matter production/plant to bulb yield was observed, it was observed that the direct contribution throughout the 3 seasons were positive and very large, with the largest contribution of 0.7179 in 1995/96 out of a total correlation of 0.5846. This was followed by 0.6952 in 1994/95 out of a total correlation of 0.5419. In 1996/97 the direct contribution of dry matter to bulb yield was 0.5086 out of a total of 0.4260. Indirectly, the contributions of dry matter via plant height were positive in all seasons and varied from 0.0764 in 1994/95 to 0.1403 in 1995/96 dry seasons. Similarly, the indirect contributions of dry matter/plant to bulb yield via average number of leaves/plant were positive, though very small throughout the 3 seasons. The contributions were 0.1067, 0.0034 and 0.1309 during 1994/95, 1995/96 and 1996/97 dry seasons, respectively. The contributions of dry matter/plant via CGR were negative throughout the 3

Table 49: The direct and indirect effects of different growth characters to bulb yield in 1994/95 dry season at Samaru.

Growth characters	effect through					
	Plant height	Leaves/ plant	dry matter/ plant	CGR	RGR	Total correlation
Plant height	.2190a	.0709	.2427	-.1410	.0387	.4303
Leaves/plant	.0982	.1580a	.4696	-.3192	.0838	.4904
dry matter/ plant	.0764	.1067	.6952a	-.4762	.1398	.5419
CGR	.0610	.0995	.6537	-.5064a	.1577	.4655
RGR.	.0515	.0804	.5906	-.4855	.1645a	.4015

(a) direct contribution

Table 50: The direct and indirect effects of different growth characters to cured bulb yield in 1995/96 dry season at Samaru.

Growth characters	effect through					
	Plant height	Leaves/ plant	dry matter/ Plant	CGR	RGR	Total Correlation
Plant height	.3647a	.0105	.2761	-.1028	.0077	.5562
Leaves/plant	.0668	.0573a	.0424	.0010	-.005	.1670
dry matter/plant	.1403	.0034	.7179a	-.2963	.0193	.5846
CGR	.1175	-.0002	.6666	-.3191a	.0228	.4876
RGR	.0799	-.0008	.3935	-.2059	.0353a	.3020

a - direct contribution

seasons and varied from -0.4762 in 1994/95 to -0.0873 in 1996/97 dry seasons. The indirect contributions of dry matter/plant to bulb yield via RGR were positive in the first 2 seasons (1994/95 and 1995/96) but negative in the last season (1996/97) and varied from 0.1398 in 1994/95 to -0.2026 in 1996/97 dry seasons.

When the direct and indirect contributions of crop growth rate to bulb yield were examined, it was observed that out of total correlations of 0.4655, 0.4876 and 0.3232 in 1994/95, 1995/96 and 1996/97 dry seasons, respectively, CGR directly contributed negatively (-0.5064, -0.3191 and -0.0930) in all seasons. It however, contributed positively indirectly via plant height and the contributions varied from 0.0564 in 1996/97 to 0.1175 in 1995/96 dry seasons. The indirect contributions of CGR to bulb yield via number of leaves/plant were 0.0995, -0.0002 and 0.1178 in 1994/95, 1995/96 and 1996/97 dry seasons, respectively. However, the contributions of CGR to bulb yield via dry matter/plant were very high and positive throughout the 3 seasons. The contributions were 0.6537, 0.6666 and 0.4774 for 1994/95, 1995/96 and 1996/97 seasons, respectively. Contributions of CGR to bulb yield via RGR were positive. In 1994/95 (0.1577) and 1995/96 (0.0228) seasons, but negative in 1996/97 (-0.2354) dry season.

Table 51: The direct and indirect effect of different yield components to cured bulb yield in 1996/97 dry season at Samaru

Characters	Effect through					
	Plant height	Leaves/ plant	dry matter/ plant	CGR	RGR	Total correlation
Plant height	.2735a	.0535	.1422	-.0192	-.0319	.4181
Leave/plant	.0670	.2181a	.3052	-.0503	-.1210	.4190
dry matter/plant	.0765	.1309	.5086a	-.0873	-.2026	.4260
CGR	.0564	.1178	.4774	-.0930a	-.2354	.3232
RGR	.0347	.1050	.4101	-.0871	-.2512a	.2115

a - direct contributions

The total correlation between relative growth rate (RGR) and bulb yield varied from 0.4015 (1994/95) to 0.2115 (1996/97). Out of these, direct contributions of RGR to bulb yield was found to be 0.1675, 0.0353 and -0.2512 in 1994/95, 1995/96 and 1996/96 seasons, respectively. The indirect contribution of RGR via plant height was very small and varied from 0.0347 in 1996/97 to 0.0799 in 1995/96 dry seasons. Indirectly via number of leaves/plant, RGR contributed 0.0804 (1994/95), -0.0008 (1995/96) and 0.1050 (1996/97) to bulb yield, respectively. The indirect contribution of RGR to bulb yield via dry matter/plant were highest in all seasons and varied from 0.3935 in 1995/96 to 0.5906 in 1994/95 seasons. The indirect contribution of RGR via CGR were very small and negative in all seaons and varied from -0.4855 to -0.0871.

When the individual percentage contributions of all growth parameters were examined, it was noted that the percent contributions of plant height to bulb yield were 4.8%, 13.3% and 7.48% in 1994/95, 1995/96 and 1996/97 seasons, respectively (Tables 52, 53 and 54). Individual percent contributions of leaf number/plant were very small and varied from 0.33% in 1995/96 to 4.76% in 1996/97 seasons. The dry matter/plant has the highest percent contributions to bulb yield in all seasons. This varied from 25.87% in 1996/97 to 51.54% in 1995/96 dry

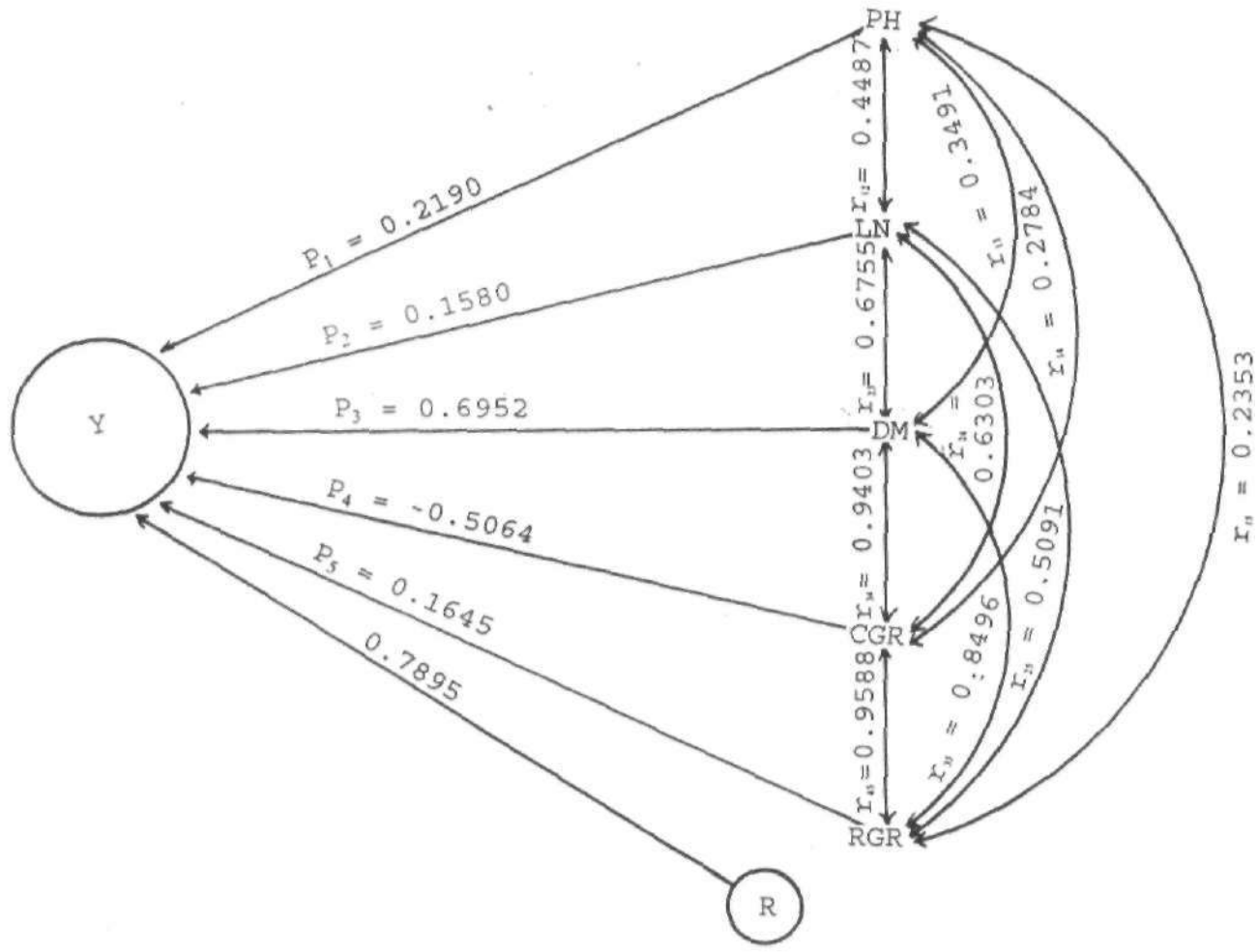


Fig (i) Path diagram showing inter-relations of bulb yield (kg/ha) and some growth characters in 1994/95 dry season at Samaru.

Key

PH = Plant height

LN = Ave. No. of leaves/plant

OM = Dry matter/plant

CGR = Crop growth rate

RGR = Relative growth rate

R = residual

Y = Bulb yield

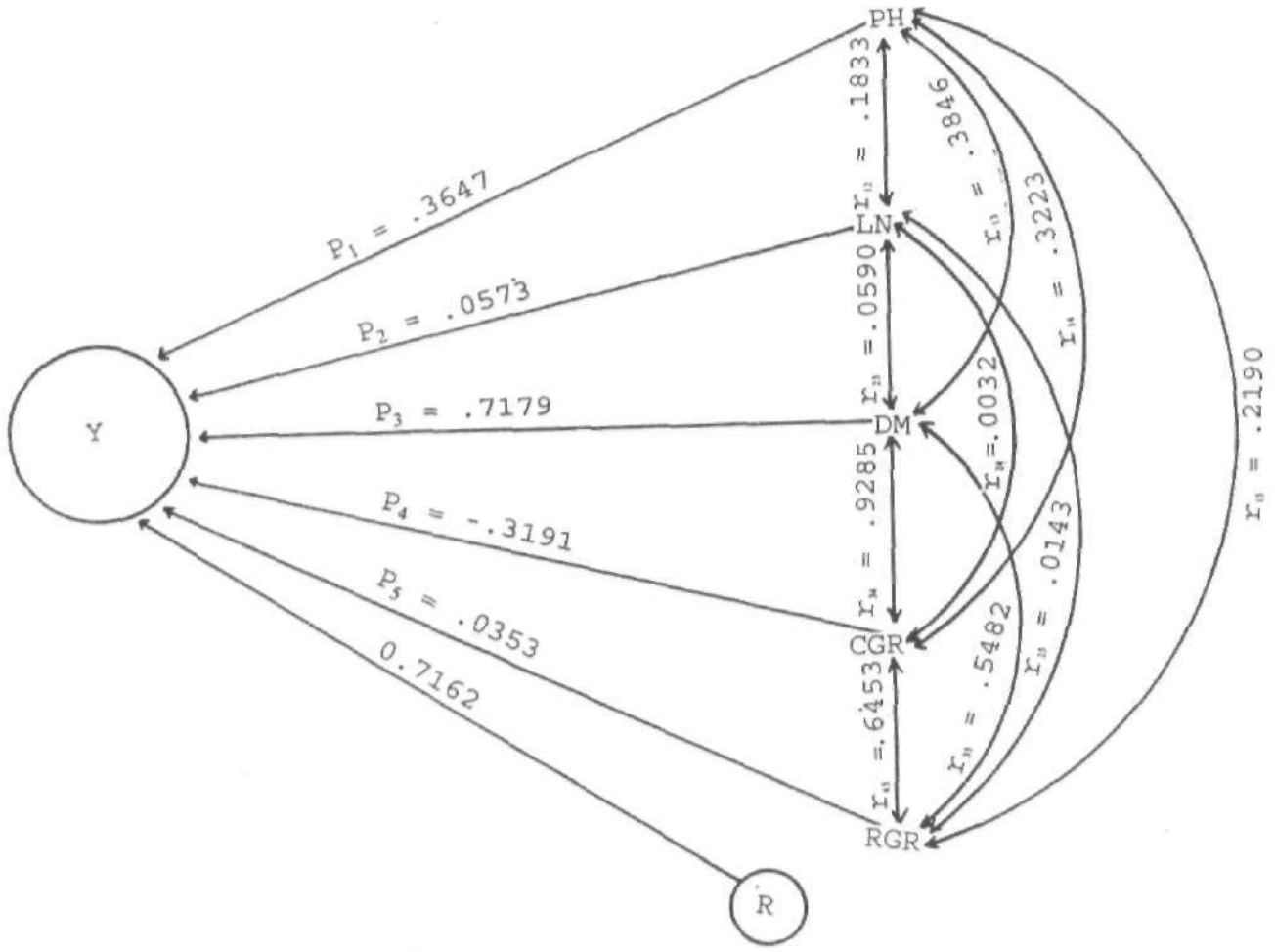


Fig (ii) Path diagram indicating inter-relations of bulb yield (kg/ha) and some growth characters in 1995/96 dry season at Samaru.

Key

PH = Plant height

LN = Ave. No. of leaves/plant

OM = Dry matter/plant

CGR = Crop growth rate

RGR = Relative growth rate

R = residual

Y = Bulb yield

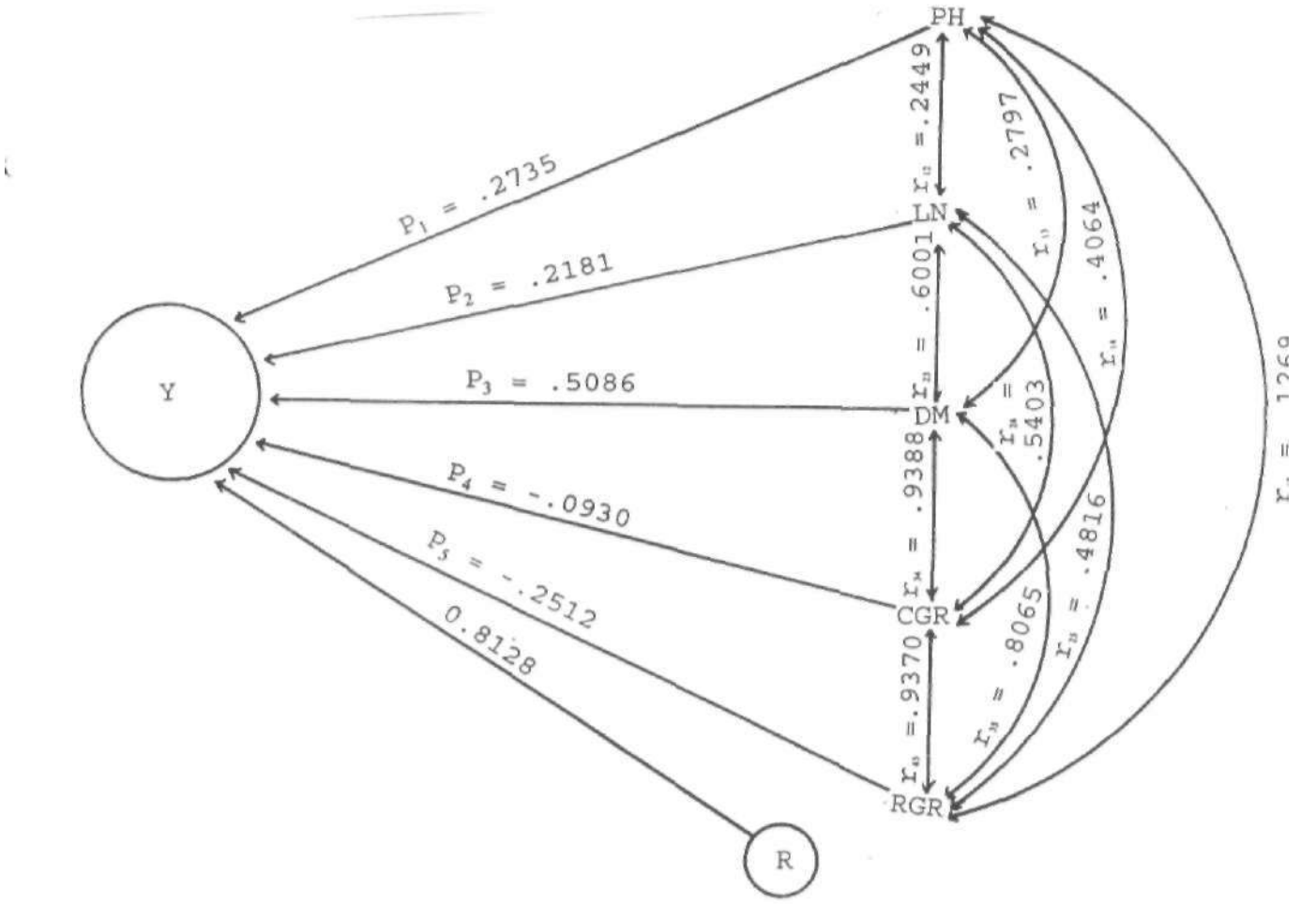


Fig. (iii): Path diagram showing inter-relations of bulb yield (kg/ha) and some growth characters in 1996/97 dry season at Samaru.

Key

PH = Plant height

LN = Ave. No. of leaves/plant

OM = Dry matter/plant

CGR = Crop growth rate

RGR = Relative growth rate

R = residual

Y = Bulb yield

seasons. Crop growth rate also contributed significantly high percentage in 1994/95 (25.64%) and 1995/96 (10.18%) seasons, while in 1996/97 the contribution was very small (0.87%). The percent contributions of relative growth rate (RGR) to bulb yield were 2.71% (1994/95) 0.13% (1995/96) and 6.31% (1996/97).

When the combined contributions of two characters to bulb yield were examined, it was observed that the percent contribution of plant height and number of leaves/plant was 2.9%, 0.77% and 2.92% in 1994/95, 1995/96 and 1996/97 dry seasons respectively. The combined contribution of plant height and dry matter were positive and very high in all seasons; 10.63% (1994/95), 20.14% (1995/96) and 7.78% (1996/97). The combined percent contributions of plant height and CGR when examined was found to be negative in all seasons and varied from -7.15% in 1995/96 to -1.05% in 1996/97 dry seasons. When the contribution of plant height and RGR was looked at it was found to be -1.74% in 1996/97 whereas it was positive during 1995/96 (0.56%) and 1994/95 (1.69%), seasons, respectively. The contribution of leaf number/plant and dry matter/plant was almost similar (14.8% and 13.3%) in 1994/95 and 1996/97 seasons. It was however, very small in 1995/96 season (0.49%). When leaf number/plant and CGR were examined, it was found to be negative in all seasons and varied from

Table 52: Percentage contributions of different growth characters to bulb yield in 1994/95 dry season at Samaru.

Character of yield	Percentage contributions
Individual contributions	
Plant height (cm)	4.80
Ave. Leaf number/plant	2.50
Dry matter/plant (gm)	48.33
CGR g/dm^2/wk	25.64
RGR g/g/wk	2.71
Combined contributions	
Plant height and Ave. Leaf number/plant	2.90
Plant height and dry matter/plant	10.63
Plant height and CGR	-6.18
Plant height and RGR	1.69
Ave. leaf number/plant and dry matter/plant	14.84
Ave. leaf number/plant and CGR	-10.09
Ave. leaf number/plant and RGR	2.65
Dry matter/plant and CGR	-66.21
Dry matter/plant RGR	19.43
CGR and RGR	-15.97
Residual	62.34
Total	100.00

Table 53: Percentage contributions of different growth characters to cured bulb yield in 1995/96 dry season at Samaru.

Growth characters	Percentage contributions
Individual contributions	
Plant height (cm)	13.30
Ave. leaf number/plant	0.33
Dry matter/plant	51.54
CGR g/dm2/wk	10.18
RGR g/gwk	0.13
Combined contributions	
Plant height and Ave. leaf number/plant	0.77
Plant height and dry matter/plant	20.14
Plant height and CGR	-7.50
Plant height and RGR	0.56
Ave. leaf number/plant and dry matter/plant	0.49
Ave. leaf number/plant and CGR	-0.01
Ave. leaf number/plant and RGR	-0.02
Dry matter/plant and CGR	-42.54
Dry matter/plant and RGR	2.78
CGR and RGR	-1.45
Residual	51.30
Total	100.00

Table 54: Percentage contributions of different growth attributes to cured bulb yield in 1996/97 dry season at Samaru.

Growth characters	Percentage contributions
Individual contributions	
Plant height (cm)	7.48
Ave. leaf number/plant	4.76
Dry matter/plant	25.87
CGR g/dm2/wk	0.87
RGR g/gwk	6.31
Combined contributions	
Plant height and Ave. leaf number/plant	2.92
Plant height and dry matter/plant	7.78
Plant height and CGR	-1.05
Plant height and RGR	-1.74
Ave. leaf number/plant and dry matter/plant	13.31
Ave. leaf number/plant and CGR	-2.19
Ave. leaf number/plant and RGR	-5.28
Dry matter/plant and CGR	-8.88
Dry matter/plant and RGR	-20.61
CGR and RGR	4.38
Residual	66.07
Total	100.00

10.10% in 1994/95 to -0.01% in 1995/96 seasons. The combined contribution of number of leaves/plant and RGR was negative during 1995/96 and 1996/97 seasons (-0.02% and -5.28%) but positive in 1994/95 season (2.65%). Dry matter production/plant and CGR combined contribution was negative and high in all the 3 seasons. It was -66.2%, -42.5% and -8.88% in 1994/95, 1995/96 and 1996/97, respectively. The combined percent contribution of dry matter/plant and RGR was negative in 1996/97 (-20.61%) but positive in 1994/95 (19.43%) and 1995/96 (2.78%) seasons. The combined contribution of CGR and RGR was negative in 1994/95 and 1995/96 (-15.97% and -1.45%) but positive in 1996/97 (4.38%) seasons. The residual in the 3 seasons was found to be 62.34%, 51.30% and 66.07%, respectively.

The study of the direct and indirect effects of different yield components on the final bulb yield in 3 seasons are indicated on tables 55, 56, and 57, while the path - diagrams are presented in figures 4, 5 and 6 for the 1994/95, 1995/96 and 1996/97 dry seasons, respectively. The total correlation between bulb weight and bulb yield was highly significant and varied from 0.9702 in 1994/95 to 0.9999 in 1995/96 and 1996/97 seasons respectively. Out of these, the bulb weight directly contributed 1.1472, 0.9986 and 1.0001 in 1994/95, 1995/96 and 1996/97 dry seasons, respectively.

Table 55: The direct and indirect contributions of different yield components to bulb yield in 1994/95 dry season at Samaru.

Yield components.	effect through				
	Bulb weight	Bulb size	No.clove/ bulb	clove weight	Total correlation
Bulb weight	1.1472a	.0297	-.0394	-.1673	0.9702
Bulb size	1.1025	.0309a	-.0410	-.1609	0.9317
No. cloves/bulb	.2735	.0077	-.1654a	.2305	0.3463
Clove weight	.5466	.0142	.1086	-.3512a	.3182

(a) direct contribution

Table 56: The direct and indirect effect of different yield components to cured bulb yield in 1995/96 dry season at Samaru.

Characters	effect through				
	Bulb weight	Bulb size	No Cloves/ Bulb	Clove weight	Total Correlation
Bulb weight	.9986a	.0002	.0010	-.0001	.9999
Bulb size	.4368	.0004a	.0005	-.0001	.4377
No cloves/bulb	.6662	.0001	.0016a	-.0004	.6675
Clove weight	-.0825	-.0001	-.0010	-.0006a	-.0842

a - direct contributions

Table 57: The direct and indirect effects of different yield components to cured bulb yield in 1996/97 dry season at Samaru.

Characters	Effect through				
	Bulb weight	Bulb size	No clove/ bulb	Clove weight	Total correlation
Bulb weight	1.0001a	.0003	-.0002	-.00024	0.9999
Bulb size	.4404	.0006a	-.0003	.0001	.4409
No. cloves/bulb	.3231	.0002	-.0007a	.0006	.3233
Clove weight	.2682	-.0001	.0005	-.0009a	.2677

a - direct contributions

Indirectly via bulb size, bulb weight contributed very little; 0.0297, 0.0002 and 0.0003 for the 1994/95 1995/96 and 1996/97 seasons. Contribution of bulb weight indirectly via number of cloves/bulb was negative in 1994/95 (-0.0394) and 1996/97 (-0.0002) while it was positive but very small in 1995/96 (0.001) season. The indirect contribution of bulb weight to bulb yield via clove weight was negative in all seasons and varied from -0.1673 to -0.00024.

When the direct and indirect contribution of bulb size to bulb yield was examined, it was observed that bulb size directly contributed very little in all seansons, ranging from 0.0004 in 1995/96 to 0.0309 in 1994/95 season. Bulb size however, indirectly contributed largely to bulb yield via bulb weight in all seasons. The indirect contributions were 1.1025, 0.4368 and 0.4404 in 1994/95, 1995/96 and 1996/97 seasons out of total correlations of 0.9317, 0.4377 and 0.4409 for the respective seasons. The indirect contribution of bulb size to bulb yield via number of cloves/bulb was regative in 1994/95 (-0.0410) and 1996/97 (-0.0003) while in 1995/96 season it was positive, though very neglible (0.0005). Similarly, bulb size indirectly contributed negatively to bulb yield via clove weight in 1994/95 (0.1609) and 1995/96 (-0.0001) but contribution was positive in 1996/97 (0.0001) season.

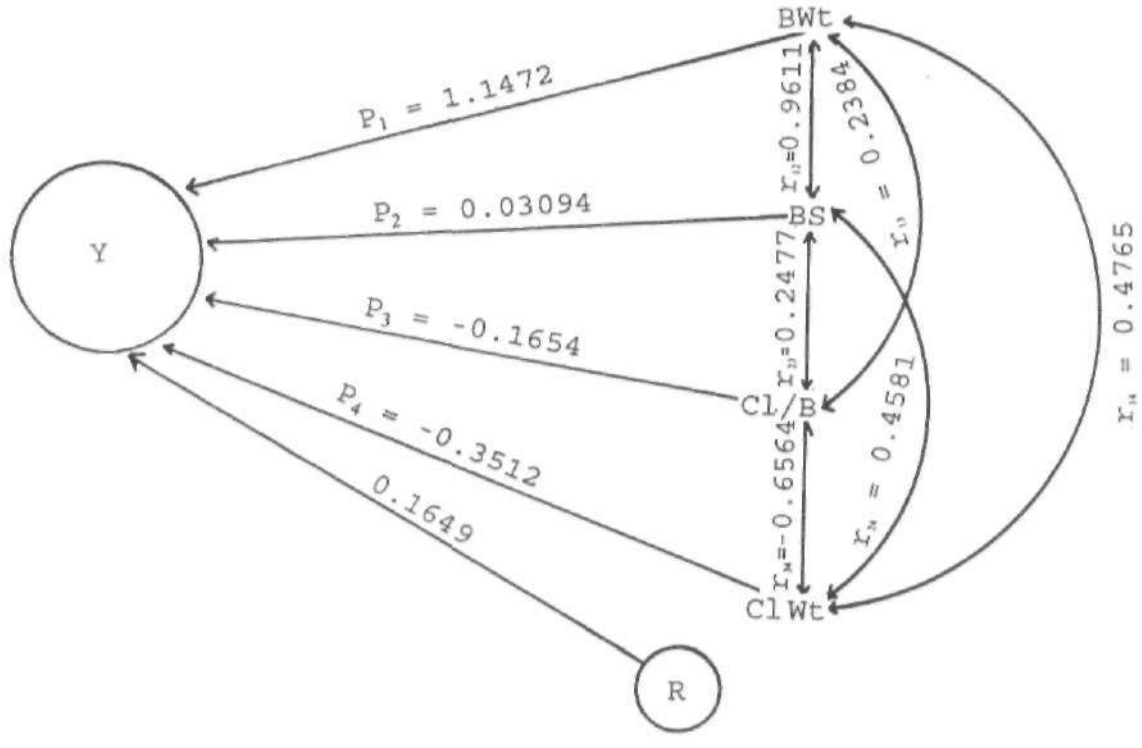


Fig (iv): Path diagram showing inter-relations of bulb yield (kg/ha) and some yield components in 1994/95 dry season at Samaru.

Key

Bwt = Ave. bulb weight

BS = Bulb size

Cl/B = Ave. No. of cloves/bulb

Clwt = Ave. clove weight

R = Residual

Y Bulb yield.

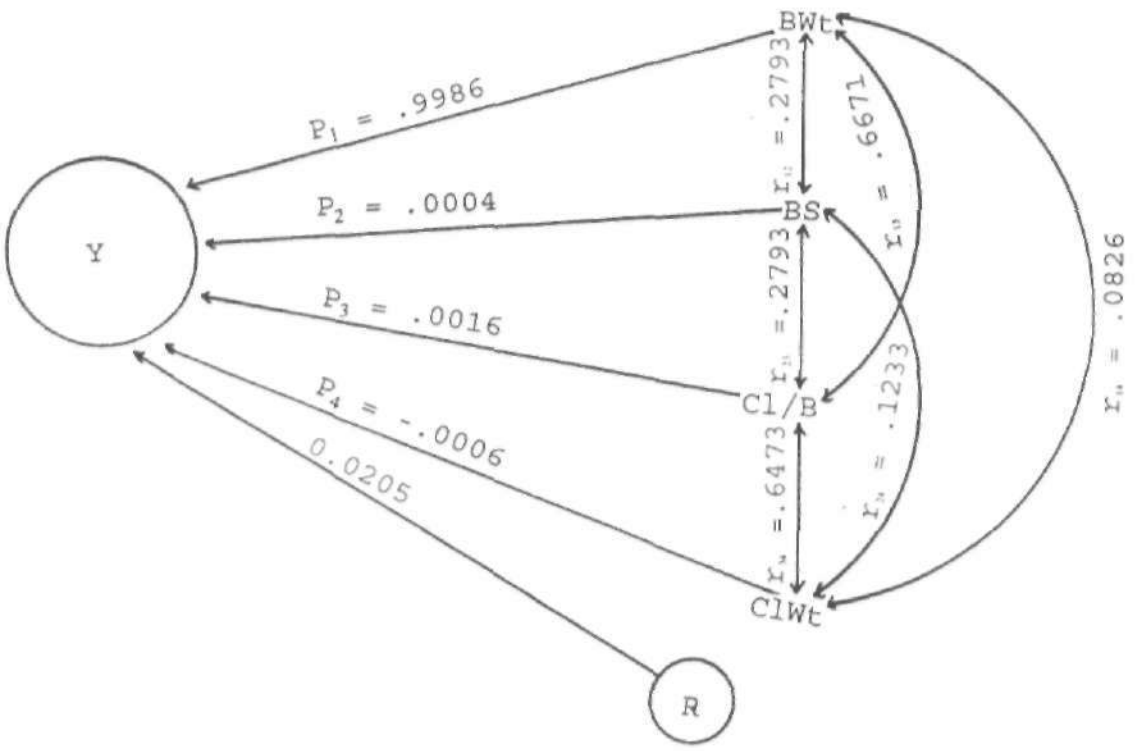


Fig (v): Path diagram showing inter-relations of bulb yield (kg/ha) and some yield components in 1995/96 dry season at Samaru.

Key

Bwt = Ave. bulb weight

BS = Bulb size

Cl/B = Ave. No. of cloves/bulb

Clwt = Ave. clove weight

R = Residual

Y Bulb yield.

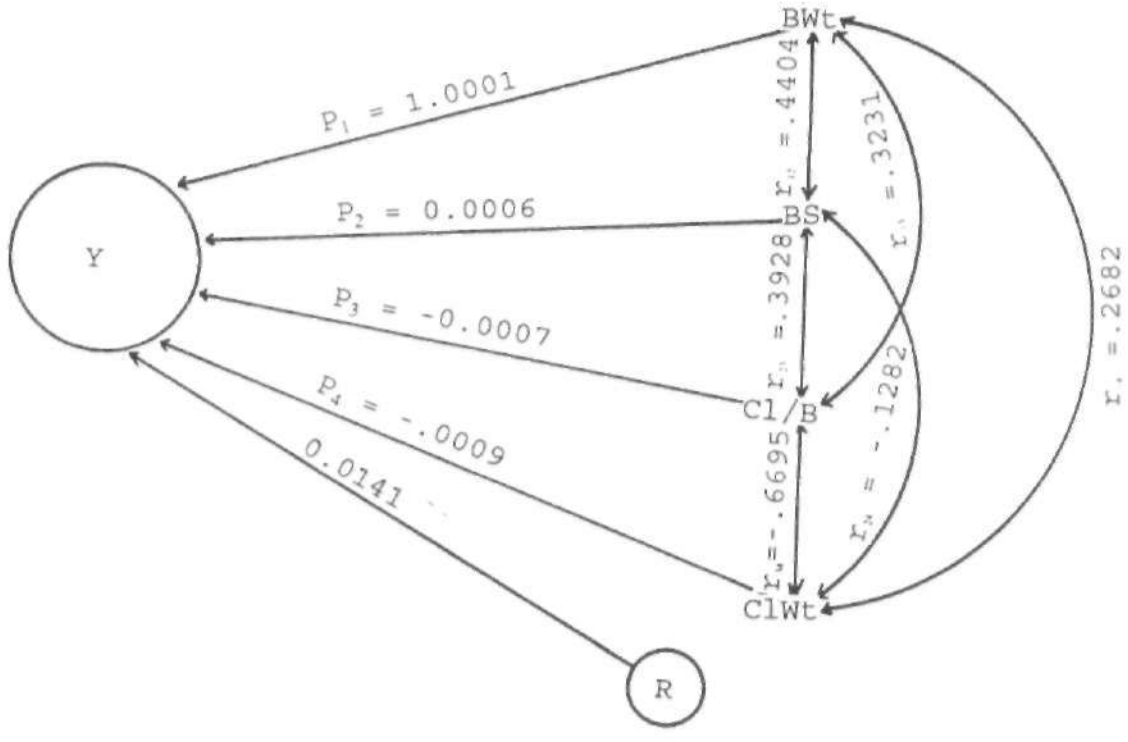


Fig. (vi): Path diagram showing inter-relations of bulb yield (kg/ha) and some yield components in 1996/97 dry season at Samaru.

Key

Bwt = Ave. bulb weight

BS = Bulb size

Cl/B = Ave. No. of cloves/bulb

Clwt = Ave. clove weight

R = Residual

Y Bulb yield.

The direct contribution of number of cloves/bulb was negative in 1994/95 (-0.1654) and 1996/97 (-0.0007) seasons but was positive, though small in 1995/96 (0.0016) season. Out of the total correlation of 0.3463, 0.6675 and 0.3233 between number of cloves/bulb and bulb yield in 1994/95, 1995/96 and 1996/97 seasons, the indirect contribution of number of cloves/bulb via bulb weight was highest in all easons and varied from 0.2735 in 1994/95 to 0.6662 in 1995/96 seasons. Indirect contribution of number of cloves/bulb via bulb size was very small in all seasons and varied from 0.0001 in 1995/96 to 0.0077 in 1994/95 seasons. The contribution of number of cloves/bulb via clove weight was high in 1994/95 (0.2305) negative in 1995/96 (-0.0004) and positive though small in 1996/97 (0.0006) season.

The direct contribution of clove weight to bulb yield was negative in all seasons. All indirect contributions of clove weight were negligible and negative in 1995/96 season (Table 56). However, the indirect effect of clove weight on bulb yield via bulb weight was high, in 1994/95 (0.5466) and 1996/97 (0.2682) seasons. The effects of clove weight via bulb size and number of cloves/bulb were very small in 1994/95 and 1996/97. The contributions varied from -0.0001 in 1996/97 to 0.1086 in 1994/95 seasons.

The individual and combined percentage contributions of the yield components to bulb yield during the 1994/95, 1995/96 and 1996/97 dry seasons are presented in Tables 58, 59 and 60 respectively. When the individual percent contributions to bulb yield were examined, it was observed that bulb weight contributed 131.61%, 99.72% and 100.02% in 1994/95; 1995/96 and 1996/97 seasons, respectively. In all seasons, bulb size, however, contributed less than 0.1%. The percent contributions of number of cloves/bulb to bulb yield was 2.74% in 1994/95 and less than 0.01% in the 1995/96 and 1996/97 seasons. Similarly, clove weight contributed 12.33% in the first season while its contributions in subsequent seasons were less than 0.001%.

When the combined contributions of these characters to bulb yield was critically examined, it was observed that bulb weight and bulb size contributed 6.82%, 0.035% and 0.053% in the 1994/95, 1995/96 and 1996/97 seasons, respectively. The combined contribution of bulb weight and number of cloves/bulb were negative in 1994/95 (-9.05%) and 1996/97 (-0.045%) while in 1995/96 it was positive though very small (0.213%). When the combined contributions of bulb weight and clove weight were examined, it was observed that all contributions were small and negative in all seasons and varied from -38.40% in 1994/95 to -0.048% in 1996/97 seasons. The combined

Table 58: Percentage contributions of different yield characters to yield in 1994/95 dry season at Samaru.

Character of yield	Percentage contributions
Individual contributions	
Bulb weight (gm)	131.61
Bulb size (cm)	0.096
No of clove/bulb	2.74
Ave. clove weight (gm)	12.33
Combined contributions	
Bulb weight and Bulb size	6.82
Bulb weight and No of cloves/bulb	-9.05
Bulb weight and Ave. clove weight	-38.40
Bulb size and No of cloves/bulb	-0.25
Bulb size and Ave. clove weight	-0.99
No. of clove/bulb and Ave. clove weight	-7.63
Residual	2.72
Total	100.00

Table 59: Percentage contributions of different yield attributes t
cured bulb yield in 1995/96 dry season at Samaru

Yield charaters	Percentage contributior
Individual contributions	
Bulb weight (gm)	99.72
Bulb size (cm)	$10.x\ 10^{-5}$
No. of cloves/bulb	2.5×10^{-5}
Ave clove weight (gm)	3×10^{-5}
Combined contributions	
Bulb weight and bulb size	0.035
Bulb weight and No. of cloves/bulb	0.213
Bulb weight and Ave. Clove weight	-0.0099
Bulb size and No. of clove/bulb	10×10^{-5}
Bulb size and Ave. cloves/weight	-5.9×10^{-5}
No of cloves/bulb and Ave. Clove weight	1.2×10^{-4}
Residual	0.042
Total	100.00

Table 60: Percentage contributions of different yield components to cured bulb yield in 1996/97 dry season at Samaru

Yield charaters	Percentage contributions
Individual contributions	
Bulb weight (gm)	100.02
Bulb size (cm)	3×10^{-5}
No. of cloves/bulb	4×10^{-5}
Ave clove weight (gm)	8×10^{-5}
Combined contributions	
Bulb weight and bulb size	0.053
Bulb weight and No. of cloves/bulb	-0.045
Bulb weight and Ave. Clove weight	-0.048
Bulb size and No. of clove/bulb	-2×10^{-5}
Bulb size and Ave. cloves/weight	-1×10^{-5}
No of cloves/bulb and Ave. Clove weight	-8×10^{-4}
Residual	0.02
Total	100.00

contribution of bulb size and number of cloves/bulb were negative in 1994/95 (-0.25%) and 1996/97 (-2×10^{-5}). Bulb size and clove weight contributed negatively to bulb yield in all seasons; while number of cloves/bulb and clove weight contributed less than 0.01% in all seasons. The unaccounted residuals for the 3 seasons were 2.72%, 0.042% and 0.02% during 1994/95, 1995/96 and 1996/97 seasons, respectively.

4.3.2 Polynomial Response of Garlic yield to Nitrogen, Phosphorus and Irrigation Interval.

When the sum of squares due to nitrogen were aportioned into various levels of response variances, along with their respective degrees of freedmom, it was observed that none of the response (Linear and quadratic) was found to be statistically significant in all the 3 seasons for nitrogen (Appendices v,vi and vii). It was further noted that the cubic response can not be tested in these experiments as there is no variance for deviation and degrees of freedom available to test it. When no response was singled out to be statistically better than the others using analysis of variance, the data were further investigated by using chi-square (U^2) test of significance and calculating the square of deviations between observed and expected yields. In both cases, it was observed that the quadratic response is a better fit to the data than the linear response (Tables 61, 62 and 63).

Similarly, when the sum of squares due to phosphorus and irrigation interval (Appendices v, vi and vii) were aportioned into the various degrees of responses, along with their respective degres of freedom, it was noted that none of the responses (both Linear and quadratic) were found to be statistically significant in all seasons and for all factors. It was however, observed that the

Table 61: Polynomial response of bulb yield to applied nitrogen phosphorus and irrigation intervals in 1994/95 dry seasc at Samaru

Treatments	Observed bulb yield (kg/ha)	Expected bulb yield (kg/ha) Linear	Ψ^2	Quadratic	Ψ^2
Nitrogen (kg N/ha)					
0	7485	8711.77	201.06	7548.00	0.530
75	10076	8952.45	125.28	10058.75	0.030
150	10419	9193.12	144.23	10375.63	0.181
225	8472	9433.80	109.19	8498.75	0.085
			$\Sigma\Psi^2$ = 579.76**		$\Sigma\Psi^2$=0.826N
Phosphorus (kg P_2O_5/ha)					
0	7381.0	7571.88	4.936	7381.04	$2x10^{-7}$
75	9457.0	9075.63	15.379	9456.29	$5.33x10^{-5}$
150	10388.0	10579.38	3.526	10384.04	$1.51 x10^{-3}$
			$\Sigma\Psi^2$ = 23.84**		$\Sigma\Psi^2$=0.0002N
Irrigation Interval (day)					
5	11140.0	10663.13	20.413	11139.65	$1.09 x 10^{-5}$
10	8122.0	9075.63	111.969	8122.35	$1.5 x 10^{-5}$
15	7965.0	7488.13	28.551	7964.55	$2.54 x 10^{-5}$
			$\Sigma\Psi^2$ = 160.93**		$\Sigma\Psi^2$=$5.13x10^{-5}$N

Regression Equations:

for N: YL = 8711.772 + 3.209x
YQ = 7548.126 + 48.1x - .195x^2
P = YL = 7571.88 + 20.05x
YQ = 7381.04 + 35.32x - .102x^2
I = YL = 12250.63 + 317.5x
YQ = 17016.45 - 1461.31x + 57.19x^2

Table 62: Polynomial response of bulb yield to applied nitrogen, phosphorus and irrigation intervals in 1995/96 dry season at Samaru

Treatments	Observed bulb yield (kg/ha)	Expected bulb yield (kg/ha) Linear	Ψ^2	Quadratic	Ψ^2
Nitrogen (kg N/ha)					
0	4959	5792.00	139.93	5091.00	3.50
75	6863	6081.50	88.99	6744.75	2.06
150	6980	6371.00	53.13	7071.00	1.19
225	5952	6660.50	84.34	6069.75	2.33
			$\Sigma\Psi^2$ = 366.39**		$\Sigma\Psi^2$= 9.09NS
Phosphorus (kg P_2O_5/ha)					
0	4998.00	5099.00	2.04	4998.48	$3x10^{-7}$
75	6431.00	6231.50	6.19	6418.36	0.025
150	7258.00	7364.00	1.55	7252.50	0.004
			$\Sigma\Psi^2$ = 9.78*		$\Sigma\Psi^2$= 0.029NS
Irrigation Interval (day)					
5	8016.00	7685.00	13.67	8015.50	$3.1x10^{-5}$
10	5567.00	6230.00	78.96	5563.00	$2.9x10^{-3}$
15	5105.00	4775.00	21.33	5095.50	$1.8x\ 10^{-2}$
			$\Sigma\Psi^2$ = 113.96**		$\Sigma\Psi^2$=0.021NS

Regression Equations:

for N: YL = 5792 + 3.86x
YQ = 5091 + 30.9 $-0.118x^2$
P = YL = 5099 + 15.1x
YQ = 4998 + 23.1x $-0.0538x^2$
I = YL = 9140 - 291x
YQ = 12453- 1086x + $39.7x^2$

Table 63: Polynomial response of bulb yield to applied nitrogen, phosphorus and irrigation intervals in 1996/97 dry season at Samaru

Treatments	Observed bulb yield (kg/ha)	Expected bulb yield (kg/ha) Linear	Ψ^2	Quadratic	Ψ^2
Nitrogen (kg N/ha)					
0	7993	9122.78	159.69	8124.94	2.18
75	10204	9231.23	92.74	10178.25	0.065
150	10291	9339.68	87.94	10347.19	0.307
225	8558	9448.13	92.58	8631.75	0.636
			$\Sigma\Psi^2$ = 432.95**		$\Sigma\Psi^2$=3.188NS
Phosphorus (kg P_2O_5/ha)					
0	7733.00	7904.73	3.814	7721.82	0.016
75	9652.00	9286.98	13.804	9652.60	$3.7x10^{-5}$
150	10486.00	10669.23	3.202	10485.95	$2x10^{-7}$
			$\Sigma\Psi^2$ = 20.82**		$\Sigma\Psi^2$=0.016NS
Irrigation Interval (day)					
5	11538.00	11086.09	17.700	11538.35	$1.06x10^{-5}$
10	8382.00	9286.64	97.635	8382.90	$9.66x10^{-5}$
15	7939.00	7484.19	25.723	7940.45	$2.65x10^{-4}$
			$\Sigma\Psi^2$ = 141.06**		$\Sigma\Psi^2$=0.0004NS

Regression Equations:

for N: $YL = 9122.78 + 1.446x$

$YQ = 8124.94 + 39.94x - .1675x^2$

P = $YL = 7904.73 + 18.43x$

$YQ = 7721.82 + 33.06x - .09755x^2$

I = $YL = 12885.54 - 359.89x$

$YQ = 17406.80 - 1444.99x + 54.26x^2$

deviations from linearity for both phosphorus and irrigation interval, in all seasons and the combined analysis, were highly significant. Thus, indicating linear response to be the poorest fit for the data. When no response was singled out to be statistically better using analysis of variance, the test for fitness was further evaluated using chi-square test of signnificance (Tables 61, 62 and 63). It was observed from the sum of chi-square values that the deviations from linearity were significant in all seasons, while the deviations for quardratic response were not significant, indicating quadratic response to be better than the linear response.

CHAPTER FIVE

5.0 DISCUSSION

The lower growth parameters recorded during the 1995/96 season as compared with the other two seasons (1994/95 and 1996/97) is attributed to differential climatic conditions during the growing cycle of the garlic crop, especially, the differences in temperatures. Garlic requires cool dry weather during vegetative growth. However, in 1995/96, the mean minimum and maximum temperatures (appendix II) were higher than in 1994/95 and 1996/97 (appendices I and III), consequently affecting the vegetative growth of the crop. Higher temperatures as observed in 1995/96 season resulted in higher evaporative demand on the soil moisture, thus resulting in higher capillary rise of the soil moisture, which left the upper soil profile, where crop roots are located, dry, consequently affecting nutrients and moisture uptake.

Similarly the yield components as well as the bulb yield were lower in 1995/96 trial as compared to other seasons probably due to the detrimental effect of higher temperatures during vegetative period. This resulted in lower number of leaves per plant, lower photosynthetic activities, which were later manifested in the yield attributes that have direct bearing on the size of the sink. Similar results were reported on onions by Klar et

al., (1977), who also noted that higher temperatures during the vegetative phase of onions affected leaf number, leaf area and height of plants, which all affected dry matter production, decreased growth rate of crops and finally affected all yield attributes as well as the final bulb yield.

Effect of Nitrogen

Among the most important nutrient elements known to promote growth and development, nitrogen has been identified to play major roles in the functions of cell protoplasm. Nitrogen ensures healthy plant growth, which is usually manifested by increased crop vigour, size and the deep greenish colour of the foliage. Crops, like garlic when well fertilized with nitrogenous fertilizers generally grow vigourously. The increase in plant height, leaf number per plant and dry matter production per plant, with increasing rate of nitrogen upto 75kg N/ha could be attributed to the positive influence of nitrogen on cell division, cell elongation, cell expansion, synthesis of essential amino acids, enzymes, and plant chlorophyll, which all affected the general vigour of the crops. Higher number of leaves per plant indicates more photosynthetic surfaces, consequently, more assimilate production and translocation. This could have direct positive effects on the rate and amount of dry matter produced per plant. Nitrogen has also been reported by

Nehra et.al., (1988) to significantly increase the assimilatory leaf area of crops and thus influencing positively, the size of photosynthetic apparatus. Similar results were reported by Borabash and Kochina (1987) and Singh et. al., (1984). The lack of significant increase in plant height, leaf number per plant and dry matter production per plant as a result of increased N application beyond 75Kg N/ha could be explained on the basis that 75kg N/ha appears optimum for maximum effect on the physiology and morphology of garlic crop in Nigeria. This result contradicts the findings of Borabash and Kochina (1987), who recorded 100kg N/ha; Babaji (1996) who recorded 40kg N/ha and Buwalda (1986) that recorded 80kg N/ha, respectively. The crop growth rate and relative growth rate of garlic have been observed to be affected positively by nitrogen application, which could be attributed to increase in assimilatory leaf number and size. Similar results were reported by Dyson and Watson (1971), who reported that nitrogen application increased leaf number, leaf size and thus exhibiting rapid growth due to increased photosynthetic surface per plant. The increase in number of days to maturity with the application of increasing rates of nitrogen upto 225kg N/ha could be explained on the basis that nitrogen fertilization tends to increase vegetative growth by increasing leaf area and increased chlorophyll synthesis,

thus increasing leaf area index and leaf area duration, which all increased along with the length of vegetative period.

Throughout the trial, the significant increase in average number of cloves/bulb, average bulb size and bulb weight due to increase in N levels was from 0 to 75kg N/ha. This could be due to the favourable effects of nitrogen on number of leaves per plant and plant dry matter. In garlic crop, the number of leaves per plant has direct bearings on the number of cloves/bulb, which in turn affect bulb size and bulb weight. The application of higher rates of N did not affect these parameters significantly, suggesting 75kg N/ha to be optimum. This result further confirms the findings of Escaff and Aljaro (1982) who reported positive effects of nitrogen on yield attributes of garlic; though they recommended 150kgN/ha as optimum. The average clove weight was observed to be higher under the control throughout the trial. This was due to the fact that crops not fertilized with N produced fewer leaves per plant, thus fewer number of cloves per bulb. However, the cloves, though fewer in number, received higher assimilates, thus, becoming heavier than those which have more leaves. The size and weight of bulbs from plants that were fertilized with N were larger than those under the control due to increased number of cloves, which compensated for lower average clove weight.

Babaji (1996) also recorded higher clove weight with no nitrogen application.

Fresh and cured bulb yield/ha as well as bulb phosphorus content were observed to reach maximum increase with the application of 75kg N/ha probability due to the effects of nitrogen nutrition on photosynthetic apparatus and dry matter accumulation, which all have positive effects on the yield contributing characters, and finally the bulb yield. Phosphorus uptake by plant roots is always higher when the crops grow vigorously and are healthy. Application of nitrogen to garlic boost vigour and consequently influence indirectly phosphorus uptake, which was finally translocated to the sinks. Other workers who reported positive effect of nitrogen on garlic fresh yield, cured yield and bulb phosphorus content include Maksoud et. al., (1984), Hilman and Noordiyati (1988) Bertoni et. al., (1992) and Aliudin (1978). The crude protein content of garlic bulb was highest with the application of 225kg N/ha probably due to the influence of nitrogen on synthesis of amino acids, which are the building blocks of protein. The higher the N-supply, the more the synthesis of amino acids and thus protein content. This was in conformity with the findings of Bertoni et.al., (1992) who reported that N application increased garlic bulb quality, especially protein and sulphur contents.

5.2 Effect of Phosphorus

The significant response of garlic to applied phosphorus in terms of growth and development was a result of low available phosphorus in the soils of the experimental site (Appendix IV). Garlic crop that received no phosphorus appeared shorter, with fewer leaves and low dry matter. The increase in height of plants, leaf number per plant and dry matter as a result of the application of 75kg P_2O_5/ha was probably due to the positive function of phosphorus in enzymatic reactions, energy formation and transfer through photophosphorylation, cell division and enhanced root growth and development, which increased nutrients uptake and thus increased crop vigour and growth. This result agrees with the finding of Aliudin (1978) who reported significant increase in root growth, plant height and dry matter of garlic with the application of 70kg P_2O_5/ha. It however, disagreed with the findings of Escaff and Aljaro (1982) as well as Minard (1978) who seperately reported higher rates of phosphorus for optimum vegetative growth of garlic.

The crop growth rate, relative growth rate and days to maturity were only positively affected by the application of increasing P rates from 0 to 75kg P_2O_5/ha. This could be attributed to the positive effects of phosphorus on root development, which enhances nutrients

uptake and thus enhancing efficient assimilate production and partitioning. Phosphrous has also been reported by Aliudin (1978) to enhance nitrogen uptake and assimilation, which encouraged longer leaf duration, vigorous growth and development of crops. Results of positive effect of phosphorus on the growth of garlic and other members of Alliaceae were recorded by Sauma and Iwabuchi (1982); Agrawal et. al., (1981); Kolota (1979), Hilman and Noordiyati (1988); Rhodes (1978) as well as Anez and Tavira (1986).

Supply of phosphorus at the rate of 75kg P_2O_5/ha resulted in higher number of cloves per bulb, average clove weight, bulb size and bulb weight. The significant increases were not unconnected to the fact that phosphorus application increased cell division, increased all important growth parameters, enhanced nitrogen nutrition, which all increased photosynthetic apparatus, thus, producing more assimilates, which were finally partitioned to the sinks that consequently influence final bulb yield. It was also observed through the combined analysis of the effect of phosphorus on the yield attributes that for better growth and high productivity in garlic, application of 75kg P_2O_5/ha appeared optimum. Khan et. al., (1977), Reddy and Madalageri (1978) Laughlin (1989), Khomenko and Lysyuk (1981) all reported positive effect of applied phosphorus

on yield attributes of members of Allium species.

Fresh bulb yield, cured bulb yield, bulb crude protein and phosphorus contents were significantly influenced with applied P level only upto 75kg P_2O_5/ha. The significant response was probably due to a low available soil phosphorus of the experimental site (Appendix IV). Phosphorus is an integral part of cell nucleus and photophosphorylation process of the dark reaction of photosynthesis of crops. As such supply of phosphorus to crops, especially when grown on soils with low available phosphorus, would no doubt result in increased cell activity and increased photosynthesis, which would finally affect positively, the size and quality of the sinks. These results confirm the findings of Aliudin (1978), Escaff and Aljaro (1982), Borabash and Kochina (1987), Henriksen (1987) and Haggag et.al., (1986) on the positive effects of applied phosphorus on yield and quality of bulbs of members of Alliaceae family. Phosphorus is important in energy metabolism and thus provide energy for protein synthesis.

Effect of Irrigation

The 5-day irrigation interval resulted in taller plants, higher number of leaves/plant and dry matter production. This was because the soil type of the experimental site was sandy loam (appendix IV) thus loss of water through deep percolation and evaporation from

soil surface would be great, thus infrequent irrigation under such condition, especially to a crop like garlic, (with shallow root system) would no doubt affect negatively, the performance of the crop, especially the growth and development of the crop. The 5-day interval appeared to meet water needs of the crop, especially when grown on light soils. Similar report was recorded by Scalopi et.al., (1971) who noted significant increase in average leaf number per plant, dry matter production and plant height with frequent but light irrigation. Other workers who reported positive effect of frequent irrigation on vegetative growth of garlic include Sula (1989), Carrijo et.al., (1982) and Suh (1987). Availability of water in the crop root zone is very essential for transpiration and tissue formation. Longer irrigation interval resulted in reduced tissue formation, resulting from decreased nutrients and water uptake.

Crop growth rate, relative growth rate and number of days to maturity were highest with 5-day irrigation interval probably due to enchanced moisture availability to crops, which also increased solubility and availability of nutrients to crops. This resulted in increased crop vigour, through increased leaf number and size, thus influenceing rate of growth and maturity. Selinger and Hubner (1984) noted frequent irrigation to increase crop growth rate and delays maturity. Nassar and

Waly (1977) and Bottcher et.al.,(1979) independendently noted that frequent irrigation increased crop growth rate, relative growth rate but reduced storability of onion crop, while Duranti and Barbieri (1986) recorded increased growth of garlic with frequent irrigation.

The average number of cloves/bulb, average clove weight, bulb size and bulb weight, which were the major yield components in garlic, were very much increased with 5-day irrigation interval. It was as a result of the favourable effect of adequate moisture in the root zone on the vegetative growth characters of the crop. The parameters leaf number/plant, dry matter/plant and plant height have direct bearing on the yield. This result is in conformity with the findings of Donnari et.al., (1978) Scalopi et. al., (1971), Lazzari, et.al., (1978), Abidin and Karti (1989), Chung (1989) and Carrijo et al (1982) all of who reported increase in yield attributes with frequent light irrigation of garlic crop. All nutrients applied to the crop could not be fully utilized unless they are in soil solution. As such, fertilizer application to garlic crop that was irrigated at longer intervals, especially when grown on light soils, would become detrimental to the roots of the crop as reported by Suh (1987).

Fresh bulb and cured bulb yields and bulb phosphorus contents were the highest with 5-day irrigation

frequency, still indicating the positive effects of adequate moisture on growth characters and yield attributes, which have direct bearings on the final yield as well as the quality of bulbs harvested. Adequate moisture helps to make soil applied phosphorus readily soluble and available for uptake by roots, thus culminating in higher phosphorus contents in bulbs. This result agreed with Choi et.al., (1980) who reported that garlic yields were increased by 84% when 30mm each of water was applied at 5-day irrigation interval. Other workers who reported increased yield in garlic due to frequent light irrigation include Suh (1987), Scalopi et. al., (1971) Duranti and Barbieri (1986) and Donnari et. al., (1978). The crude protein content decreased with delayed irrigation, further indicating that water availability to crops' roots enhances uptake of nitrogen, which was later transported to the leaves for synthesis of amino acids and consequently protein synthesis. Other workers who recorded improved bulb quality with frequent irrigation included El-Tabbakh et. al., (1979) who recorded higher onion protein content with 2 weeks irrigation intervals while Abidin and Karti, (1989) recorded the best quality of garlic bulbs, with high protein, using 3 days irrigation interval; Chung (1989) with 5 days, and Hassan (1984) 10 days intervals on onions.

5.4 Nitrogen X Phosphorus Interactions

Application of 75kg N/ha along with 75kg P_2O_5/ha in (1994/95 and 1996/97) had resulted in producing taller plants that were comparable to any other combination of N and P. This could be due to the fact that nitrogen nutrition is usually enhanced by the supply of phosphorus to the plants, specifically due to the effect of phosphorus on root development, energy formation and transfer, which improves the efficiency of nutrient uptake and thus synthesis of assimilate. The results also indicated 75kg N/ha and 75kg P_2O_5/ha to be optimum for maximum growth in garlic. Similar results were reported by Khan et. al., (1977) on onion, while Borabash and Kochina (1987) recorded 90kg N/ha and 90kg P_2O_5/ha as optimum for maximum growth in garlic.

In 1996/97, statistically more leaves/plant were produced with 75kg N/ha along 75kg P_2O_5/ha indicating this combination as optimum for increased leaf number, through the positive effects of nitrogen along with phosphorus on cell division, elongation and increase in growth rate of meristematic tissues. Escaff and Aljaro (1982) recorded significant increase in leaf number of garlic with the application of nitrogen along with phosphorus at the rate of 150kg N/ha and 75kg P_2O_5/ha, respectively.

Nitrogen x phosphorus interaction of dry matter production was only significant in 1994/95 season and 75kg N/ha along with 75kg P_2O_5/ha gave comparable weight to any higher rates. This result could be explained on the basis that the soil in 1994/95 contained the lowest residual nitrogen, as such the crop response to nitrogen (in the presence of adequate level of phosphorus) was significant in relation to vegetative growth, especially the photosynthetic activities. These rates of nitrogen and phosphorus appeared optimum for maximum production of dry matter. Hilman and Noordiyati (1988) and Aliudin (1978) also recorded significant nitrogen and phosphorus interaction on garlic dry weight, though at higher rates of both N and P.

The combined analysis indicated 75kg P_2O_5/ha along with 150kg N/ha to have significantly increased number od days to maturity. This could be due to the effect of both phosphorus and nitrogen on root growth, increase in size and number of leaves as well as increased production of chlorophyll for a much longer period, which delays maturity. This result was not in conformity with findings of Aliudin (1978) who recorded 180kgN/ha along with 60kg P_2O_5/ha to have delayed maturity of garlic.

The combined analysis also revealed 75kg N/ha along with 75kg P_2O_5/ha to have significantly increased number of cloves/bulb. This indicated the positive effect of

nitrogen in combination with phosphorus on such characters like leaf number/plant, and dry matter production, which have direct bearings on the number of cloves produced per bulb. Similarly average bulb weight was influenced by N x P interaction in 1996/97 and in the combined analysis, with 75kg/ha each of N and P_2O_5 being optimum in 1996/97, while only the highest rates of N and P were superior in the combined analysis. These results also reaffirm the effect of nitrogen on vegetative growth of the plants while phosphorus was influencial on photosynthesis especially, on energy formation through photophosphorylation, which collectively and positively affected the rate and amount of assimilates production and partitioning, consequently affecting the size of the sink. This results agrees with the findings of Minerd, (1978), who attributed this response to favourable effect of N and P on growth and development of garlic crop.

Fresh bulb yield and cured bulb yield were maximum at 75kg N/ha in combination with 75kg P_2O_5/ha. This was as a result of more leaves produced per plant, more dry matter/plant, larger cloves, more cloves/bulb and heavier bulbs recorded under these rates. These parameters are major yield contributing characters as such any effort to decrease or increase these characters would ultimately affect the final bulb yield. These results contradicts those of Hilman and Noordiyati (1988), Aliudin (1978),

Escaff and Aljaro (1982) and Minard (1978) who all reported higher rates of nitrogen in combination of higher rate of phosphorus for higher bulb yield in garlic.

The crude protein content was highest under 225kg N/ha along with either 75 or 150kg P_2O_5/ha throughout the trial. This is indicative of the influence of nitrogen in synthesis of amino acids, while phosphorus has major role in energy metabolism, which provides energy for protein synthesis. It appears the application of 75kg P_2O_5/ha in combination with 225kg N/ha is adequate for maximum crude protein content of garlic bulb. Kolota (1979) recorded 200kg/ha each of N and P as optimum for high quality bulbs in onions.

5.5 Nitrogen and Irrigation Interval Interactions

The 5-day irrigation interval along with 75kg N/ha produce statistically taller plants throughout the trials indicating the favourable effect of water in bringing the nitrogen into solution for efficient uptake. Water is also essential for normal plant growth and development; thus the provision of adequate moisture through frequent irrigation, along with the application of 75kg N/ha increase cell division, elongation and increased activity in the meristematic tissues. This agrees with the work of Donnari et. al., (1978) and Lazzari et. al., (1978).

Average number of leaves/plant and dry matter production per plant were highest with the application of 75kg N/ha under 5-day irrigation inverval only in 1996/97 trial. This also explains 75kg N/ha to be adequate for tissue formation and leaves production under a frequently irrigated field. Dry matter production is a function of rate and amount of photosynthates produced by the plants leaves. Adequate moisture along with ample nutrients, especially nitrogen, would no doubt result in increased photosynthetic apparatus, which would ultimately increase the assimilate production and finally increase the rate and amount of dry matter production. The application of irrigation water at 5-day interval coupled with 75kg N/ha appeared to be optimum for increased number of leaves and dry matter production per plant. This result agrees with the findings of Singh et. al., (1987) and El-Tabbakh et. al., (1979) who all reported significant increase in leaf number and dry matter per plant on onion crop.

The increase in number of days to maturity (1994/95 and 1996/97) as a result of 5-day irrigation interval along with the application of 75kg N/ha was probably due to increase number of leaves per plant and increase dry matter production, which could probably be due to increased length of vegetative period. Nitrogen fertilization along with adequate moisture supply would increase crop vigour through increased leaf area, which

could be sustained for a much longer period, consequently prolonging the maturity of the plant. The combined analysis indicated 150kg N/ha in combination with 5-day irrigation frequency, still indicating the positive effect of moisture and nitrogen on vegetative growth of plants. Adequate moisture and nitrogen fertilization have been reported by Donnari et. al., (1978) to have maintained the foliage of garlic green for a much longer period.

Nitrogen x Irrigation interval on number of cloves/bulb and average bulb weight in 1994/95 and in 1994/95 and the combined analysis respectively, indicated these parameters to reach maximum with the application of 75kg N/ha when irrigation was given at 5-day interval. This could be attributed to the postive effect of both nitrogen and frequent irrigation on such characters as leaf number/plant and dry matter production, which have direct bearings on the number of cloves produced per bulb which in turn influence bulb weight of garlic. Nitrogen, in the persence of adequate moisture increased leaf number and size and consequently, positively affecting assimilate production, which would later be translocated to the sink, which in the case of garlic is the clove; thus affecting the weight of the bulb. These results were in agreement with the findings of Kolota (1979) and Bottcher et. al., (1977) who recorded heavier onion bulbs

with frequent irrigation, though in combination with higher rates of nitrogen.

Fresh and cured bulb yields were observed to reach maximum with the application of 75kg N/ha along with 5-day irrigation interval suggesting this combination to be optimum for higher bulb yield. The high response at this combination in relation to the yield is attributed to the positive effect of nitrogen and adequate supply of moisture on all yield attributes, which later manifested on the final bulb yield. Similar results were reported by Lazzari et. al., (1978) and Donnari et. al.,(1978), though suggesting higher rates of nitrogen coupled with frequnent but light irrigation.

The bulb crude protein and phosphorus contents reached maximum increase with the application of 75kg N/ha along with 5-day irrigation interval in the 3 season-trial, while the combined analysis indicated higher rates of 150kg N/ha. This result still confirmed the positive effects of nitrogen on protein synthesis, especially when adequate moisture was provided, which encourages rapid root development, efficient nutrients and moisture uptake, consequently influencing the quality of the bulbs. This result agrees with the work of Lazzari et al., (1978) who recorded increased bulb quality with the application of 150kg N/ha with frequent irrigation.

5.6 Phosphorus and Irrigation Interval Interaction

Phosphorus x irrigation interval on plant height and dry matter production per plant were only significant in 1996/97 and indicated 75kg P_2O_5/ha combined with 5-day irrigation interval as optimum for maximum plant height. This could be due to the effect of phosphorus on root growth, which would affect the efficiency of moisture and nutrients uptake, thus influencing positively the rate of development of the crop through increased leaf activity. Khomenko and Lysyuk (1981) also recorded tallest plants with frequent irrigation of onions but with higher rates of phosphorus. Adequate moisture in the soil might have resulted in efficient dissolution of the phosphate fertilizer, thus having adequate P in soil solution for plant uptake and utilization.

Application of 75kg P_2O_5/ha in combination with 5-day irrigation frequency resulted in delayed maturity of the crop. This is due to the fact that ample moisture in the soil coupled with P fertilization resulted in adequate phosphate in the soil solution resulting in vigorus growth, which was maintained for a much longer period. Application of phosphorus along with infrequent irrigation could have resulted in most of the applied P left undissolved and unavailable to plant roots, thus resulting in poor P nutrition which could affect even N nutrition, consequently inducing the plants to mature

much earlier. This result contradicts the findings of Nelsen and Safir (1982) who reported that onion crop continued with phosphorus nutrition even under water stress.

Crude protein and phosphorus contents of garlic bulbs were maximum with the application of 75kg P_2O_5/ha coupled with 5-days irrigation interval. this could be explained on the basis that adequate moisture supply as obtained via frequent irriation helps in rapid dissolution of the applied phosphate fertilizer which became available for plants uptake. Uptake of phosphorus by plants has also been reported by Khomento and Lysyuk (1981) to enhance nitrogen nutrition, which is involved on synthesis of amino acids, and thus crude protein content. Phosphorus helps in phosphorylation thus helps in energy metabolism that results in synthesis of proteins, including phospho-protein. Galbiatti and Castellane (1990) also recorded higher bulb phosphorus content with increasing rate of applied-P upto 240kg/ha along with ample supply of soil moisture.

Simple Correlation and Path-coefficient Studies

Positive and significant correlation was observed between almost all growth and yield characters studied, indicating interdependency amongst the characters. The negative association between clove weight and other characters as well as between number of days to maturity

and some other characters, implies that the higher the clove weight and days to maturity, the fewer will be these characters. This is true for clove weight since the higher the clove weight the fewer the number of cloves per bulb and the smaller the size of the bulb and average bulb weight, which could lower the total bulb yield. Likewise the longer it takes the plant to reach maturity, the more assimilates would be used for vegetative growth at the expense of the reproductive phase.

Correlation between bulb yield and yield components indicated bulb size, bulb weight and number of cloves per bulb to be important yield determinants. This agrees with the reports of Miko et. al.,(1995) Bichi (1997) and Babaji (1996).

The path-coefficient analysis showed that most of the growth characters registered their greatest contributions via dry matter production per plant, number of leaves per plant and relative growth rate. This was expected since dry matter production, number of leaves per plant and growth rate of plant are all synonymous with increased photosynthesis, thus greater assimilate production, which was translocated towards the sink, thus affecting the final bulb yield.

Yield attributes, however, made their greatest contribution to bulb yield through average bulb weight, bulb size and number of cloves per bulb. This indicated

bulb weight, which has the greatest direct contribution, bulb size and number of cloves/bulb as the greatest yield attributes of garlic. These results confirmed the findings of Miko et. al.,(1995) and Bichi (1997).

5.8 Polynomial Response

When the polynomial responses to nitrogen, phosphorus and irrigation interval were examined for all seasons, the deviation from observed and expected yields using Chi-square test for goodness of fit, it was observed that the sum of Chi-square for linearity were highly significant while for quadratic responses they were not significant in all seasons and for all factors, indicating that the second degree of polynomial response fitted these yield data for all factors and in all seasons, respectively.

CHAPTER SIX

6.0 SUMMARY AND CONCLUSION

Three field trials were conducted during 1994/95, 1995/96 and 1996/97 dry season at the Samaru Irrigation research farm of the Institute for Agricultural Research, Samaru (11° 11'N, 07°38'E and 686m above sea level) to study the response of garlic (Allium sativum L.) to varying levels of nitrogen, phosphorus and irrigation interval. The treatments consisted of four rates of nitrogen (0, 75, 150 and 225kg N/ha), three irrigation intervals (5, 10 and 15 days between irrigation) as the main plot treatments and three levels of phosphorus (0, 75 and 150kg P_2O_5/ha), which were used as sub-plot treatments. The treatments were replicated three times in a split-plot design.

The results from the analysed data revealed that application of increasing levels of nitrogen from 0 to 75kg N/ha increased significantly all growth characters as well as yield components and further increase beyond this rate did not produce any appreciable increase in these characters. The bulb yield as well as bulb phosphorus content were significantly increased with increasing rates of applied-N but only upto 75kg N/ha beyond which no significant effect was recorded. The bulb crude protein content however, increased significantly with increase in applied-N upto 225kg N/ha.

Increasing phosphorus levels from 0 to 75kg P_2O_5/ha had produced significant increase in all growth and yield attributes including bulb yield, bulb crude protein and phosphorus contents. Further increase in applied phosphorus did not register any appreciable increase in these characters.

The use of 5-day irrigation frequency had produced statistically taller plants, more leaves/plant, higher dry matter/plant, higher CGR, RGR as well as higher yield attributes than 10 and 15-day irrigation interval, which were in almost all cases, statistically similar. Bulb yield, bulb crude protein and phosphorus contents were also significantly higher with the application of irrigation water at 5-day interval.

Significant interactions were also recorded on some of the growth and yield characters such as plant height, dry matter, leaf number/plant, number of cloves/bulb, bulb size, bulb weight, bulb yield and quality attributes.

The results of the simple correlation analysis revealed significant positive association between and amongst some of the characters assessed. Path-coefficient analysis revealed average bulb weight to have the greatest direct effect on final bulb yield; while most significant direct contribution of growth character was from dry matter production and average number of

leaves/plant.

The greatest individual contribution of growth characters to bulb yield was from dry matter production/plant, while bulb weight had the greatest individual contribution to bulb yield amongst the yield attributes. Indirect/combined contribution was greatest via dry matter and average bulb weight.

The polynomial response of the bulb yield to applied nitrogen, phosphorus and irrigation interval using chi-square test indicated quadratic response as the better fitting curve for these data in all investigations.

The results of the study indicated that application of 75kg N/ha, and 75kg P_2O_5/ha combined with 5-day irrigation interval appeared optimum for maximum bulb yield of garlic. These levels of nitrogen and phosphorus along with irrigation frequency of 5-day had significantly increased all growth and yield attributes beyond which no appreciable increases were recorded. However, from regression analysis and polynomial responses of bulb yield to the 3 factors in the combined analysis, it was observed that the calculated optimum levels were 67.3kg N/ha, 59.2kg P_2O_5/ha and 6.2 days between irrigation.

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Appendix I. Meteorological data showing minimum and maximum temperatures, Relative humidity and Sunshine hours during 1994/95 dry season at Samaru

1994/95	Air Temperature(°C)			Relative humidity(%)			Sunshine hours.
Month	Min.	Max.	Mean	Am.	Pm.	Mean	
October '94	19.00	30.60	24.80	76.40	65.00	70.70	7.40
Novmeber '94	13.40	30.13	21.77	35.60	35.80	35.70	9.40
December ,94	11.14	27.00	19.07	37.00	26.30	31.65	NA
January '95	10.49	28.27	19.38	31.40	21.20	26.30	NA
February '95	12.44	30.28	21.36	28.45	8.10	18.28	NA
March '95	17.52	36.04	26.78	26.30	29.80	28.05	NA
April '95	19.47	36.92	28.20	41.20	31.00	36.10	NA

Source: Meteorological unit of the Institute for Agricultural Research, Samaru, Zaria

NA: Not Available.

Appendix II. Meteorological data showing minimum and maximum temperatures, Relative humidity and Sunshine hours during 1995/96 dry season at Samaru

1995/96	Air Temperature(°C)			Relative humidity(%)			Sunshine hours.
Month	Min.	Max.	Mean	Am.	Pm.	Mean	
October '95	23.80	30.60	27.20	74.30	54.60	64.45	NA
Novmeber '95	15.46	30.70	23.08	43.70	37.90	40.80	NA
December ,95	14.17	32.96	23.57	58.00	40.15	49.08	NA
January '96	10.30	32.30	21.30	23.63	16.90	20.26	NA
February '96	17.90	34.37	26.14	23.90	16.80	20.35	NA
March '96	20.80	37.68	29.24	31.70	30.70	31.20	NA
April '96	23.03	37.70	30.37	55.80	31.70	43.75	NA

Source: Meteorological unit of the Institute for Agricultural Research, Samaru, Zaria

NA: Not Available.

Appendix III: Meteorological data showing minimum and maximum temperatures, Relative humidity and Sunshine hours during 1996/97 dry season at Samaru

1996/97	Air Temperature(°C)			Relative humidity(%)			Sunshine hours.
Month	Min.	Max.	Mean	Am.	Pm.	Mean	
October '96	18.50	31.60	25.05	16.20	17.50	16.85	NA
Novmeber '96	13.10	30.50	21.80	25.20	21.50	23.35	NA
December ,96	13.00	31.03	20.02	18.37	17.47	17.92	NA
January '97	11.93	30.17	21.05	15.50	11.93	13.72	NA
February '97	12.73	30.23	21.48	17.37	13.67	15.52	NA
March '97	19.72	33.71	26.72	28.71	23.71	26.21	NA
April '97	22.71	33.81	28.26	57.31	32.10	44.71	NA

Source: Meteorological unit of the Institute for Agricultural Research, Samaru, Zaria

NA: Not Available.

Appendix IV: Physico-chemical properties of the soil of the experimental sites during the 1994/95, 1995/96 and 1996/97 dry season at Samaru.

Composition	1994/95	1995/96	1996/97
Chemical Properties			
pH in H_2O (1:1)	6.81	6.19	6.67
pH in 0.01m $Cacl_2$ (1:25)	6.36	6.02	6.20
Organic carbon (%)	0.72	0.35	0.58
Total Nitrogen (%)	0.023	0.067	0.047
Available Phosphorus (ppm).	3.37	1.73	1.60
Exchangeable cations (Meq/100gm Soil)			
Ca	1.11	0.91	1.01
Mg	0.84	0.88	0.98
K	0.21	0.18	0.19
Na	0.16	0.14	0.10
C.E.C.	5.63	5.17	5.10
Particle size distribution (%)			
Sand	58.20	56.31	62.31
Silt	13.70	13.99	15.39
Clay	28.10	29.70	22.30
Textural class	Sandy loam	Sandy loam	Sandy loam

Appendix V: Analysis of variance of Polynomial response of Garlic yield to Nitrogen levels during 1994/96 at Samaru

Source	DF	1994/95 dry season MS	F	1995/96 dry season MS	F	1996/97 dry season MS	F	Combined Analysis MS	F
Nitrogen	3	5.645×10^{8}	3.854**	2.045×10^{8}	1.402 NS	4.196×10^{8}	7.774**	2.38×10^{8}	4.304**
Linear	1	1.56×10^{5}	1.06×10^{-3}NS	1.322×10^{5}	9.07×10^{-4}	1.95×10^{4}	0.004NS	7.448×10^{4}	0.001NS
Dev. from lin.	2	8.46×10^{8}	5.77**	3.066×10^{8}	2.102 **	6.294×10^{7}	11.63**	3.57×10^{8}	6.456**
Quadratic	1	40136.33	2.74×10^{-3}NS	1.437×10^{5}	9.85×10^{-4}	5.044×10^{4}	0.009NS	6.192×10^{4}	0.0011NS
Dev. from Quad. (Cubic)	1	1.69×10^{8}	1.155NS	6.131×10^{7}	0.4205 NS	1.258×10^{8}	2.32NS	1.396×10^{7}	0.253NS
Error.	22	1.465×10^{8}		1.458×10^{8}		5.421×10^{6}		5.53×10^{7}	

Appendix VI: Analysis of variance of Polynomial response of Garlic yield to Phosphorus during 1994/95 to 1996/97 dry season at Samaru

Source	DF	1994/95 dry season MS	F	1995/96 dry season MS	F	1996/97 dry season MS	F	Combined Analysis MS	F
Phosphorus	2	8.533×10^{7}	8.828**	2.984×10^{8}	2.31**	7.236×10^{7}	18.057**	3.844×10^{8}	8.072**
Linear	1	1.507×10^{6}	0.156NS	5.128×10^{6}	0.04NS	1.263×10^{6}	0.315NS	1.194×10^{6}	0.025NS
Dev. from lin.	1	1.692×10^{8}	17.51**	5.918×10^{8}	4.58**	1.434×10^{8}	35.80**	7.677×10^{8}	16.122**
Quadratic	1	7.283×10^{4}	0.008NS	3.993×10^{5}	0.003NS	6.540×10^{4}	0.016NS	5.024×10^{4}	0.001NS
Dev. from Quad.	0	0	0	0	0	0	0	0	0
Error	48	9.665×10^{6}		1.292×10^{8}		4.007×10^{6}		4.762×10^{7}	

Appendix VII: Analysis of variance of Polynomial response of Garlic yield to Irrigation intervals during 1994/95 to 1996/97 dry season at Samaru

Source	DF	1994/95 dry season MS	F	1995/96 dry season MS	F	1996/97 dry season MS	F	Combined Analysis MS	F
Irrigation Inter.	2	1.153×10^8	7.87**	4.291×10^8	28.99**	1.386×10^8	25.57**	6.224×10^8	11.255**
Linear	1	1.680×10^6	0.115NS	1.412×10^6	0.010NS	2.159×10^6	0.398NS	1.737×10^6	0.031NS
Dev. from lin.	1	2.288×10^8	15.62**	8.569×10^8	5.880**	2.751×10^8	50.76**	1.243×10^9	22.482**
Quadratic	1	4.547×10^5	0.031NS	2.193×10^5	0.002NS	4.089×10^5	0.075NS	3.528×10^5	0.006NS
Dev. from Quad.	0	0	0	0	0	0	0	0	0
Error	22	1.465×10^7		1.458×10^8		5.421×10^6		5.53×10^7	

Appendix VIII: Composition of composite sample of garlic bulbs from the 3 seasons Experiment

Chemical component(s)	quantity in gm/100gm dry garlic sample
Protein	5.97
Fat	0.096
Fibre	0.793
Minerals	1.120
Calcium	0.271
Phosphorus	0.315
Iron	0.0013
<u>Vitamins</u>	
Thramin	5.6×10^{-5}
Riboflavin	2.12×10^{-4}
Nicotinic acid	3.16×10^{-4}
Vitamin C	1.23×10^{-2}

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