GROWTH AND YIELD OF PEPPER (*Capsicum annuum* L.) AS INFLUENCED BY NITROGEN AND PHOSPHORUS LEVELS AND PLANT DENSITY.

BY

Lamido ALIYU

A dissertation Submitted to the Post-graduate School, Ahmadu Bello University in Partial Fulfilment, of the Requirements for the Degree of Doctor of Philosophy in Agronorny

Department of Agronomy,
Faculty of Agriculture,
Ahmadu Bello University,
Zaria, Nigeria.

August, 1994.

DECLARATION

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

L. Aliyu

Student

Date 10-4-95 .....

The above declaration is confirmed.

DR. Y. YUSUF

(Chairman, Supervisory Committee)

Date 7.5.95 .....

CERTIFICATION

This dissertation titled "GROWTH AND YIELD OF PEPPER (Capsicum annuum L.) AS INFLUENCED BY NITROGEN AND PHOSPHORUS LEVELS AND PLANT DENSITY" by Lamido ALIYU meets the regulation governing the degree of Doctor of Philosophy (Agronomy) of Ahmadu Bello University and is approved for its contribution to Scientific knowledge and literary presentation.

Dr. Y. Yusuf

Chairman
Supervisory Committee

Prof. M.K. Ahmed

Member
Supervisory Committee

Dr. J.D. Olarewaju

Member
Supervisory Committee

Prof. S.T.O. Lagoke

Head,
Department of agronomy

Prof. Dalhatu Mohammed

Dean, Postgraduate School

Date ....25/9/95..

Ahmadu Bello University,
Zaria, Nigeria.

DEDICATION

To Dr. Yunusa Yusuf

and

Alhaji Yahuza M. Imam.

ACKNOWLEDGEMENTS

In the name of Allah the Beneficient the Merciful.

I will forever remain grateful to Dr. Y. Yusuf, the major supervisor for his kindness, guidance and assistance which transcends the scope of this study. Thanks are also due to Dr. J.D. Olarewaju and Prof. M.k. Ahmed for serving on the supervisory committee and who scrutinized the manuscript and made useful corrections.

I deeply appreciate the assistance I received from Professor S.T.O. Lagoke the Head, Department of Agronomy whose regular promptings were a vital catalyst in the completion of this work. The assistance received from Mr. A. Ishaku and Mallam Y. Tanko during the field work, Mr. Otitoju and Dr. A.A. Ramalan with regard to data analysis and Mr. V.O. Odigie and Mallam L. Lawal with respect to soil and plant analysis is duely acknowledged. I am also grateful to Messrs. M. Mahmud, S. Miko, M.A. Hussain Jigawa and R. Ibrahim for a wonderful espirit de corps.

I am grateful to the Authorities of Ahmadu Bello University for providing a research grant to undertake this work and also to the Director Prof. L.B. Olugbemi and Programme Leader, Hort. Crops Research Programme, I.A.R., Prof. I.D. Erinle Ahmadu Bello University for providing the research facilities. The figures were enthusiastically drawn

by A. Bello, N.A.E.R.L.S. while I thank Mr. Sani Ishaka for the excellent word processing.

Thanks are also expressed to my mother, grand mother and aunt Aisha Ahmed Hassan for their moral and material support over the years and to my wife Amina for her understanding and perseverance.

And finally, to the memory of my late father Alhaji Aliyu Gwarzo whose foresightedness, guidance and upbringing had been instrumental to my achievements in life. May Allah have mercy on him.

ABSTRACT

Field trials were carried out at Samaru during the rainy seasons of 1991 to 1993 to study the effect of levels of nitrogen (0,80,160,240, and 320KgN/ha) phosphorous (0,22 and 44KgP/ha); and plant density (20,000; 40,000 and 60,000 plants/ha) on the growth and yield of pepper (Capsicum annuum L.).

The results showed significant differences in partitioned aerial phytomass, leaf area, LAI, RGR and NAR due to the various nitrogen levels. Application of nitrogen similarly affected the concentrations of N, P and K in the shoot, the uptake of N and Ca. LAR, concentrations of Ca, Mg in both shoot and fruit as well as the uptake of Mg were not significantly influenced by nitrogen fertilization. N addition up to 160KgN/ha resulted in early flowering and maturity while fruit size was increased up to 320Kg N/ha. Pooled data revealed that maximum fruit yield was obtainable with 240KgN/ha whilst seed yield was maximized at 320kgN/ha.

Applied phosphorus affected partitioned aerial phytomass compared with the control but without any significant difference between the two phosphorus rates. RGR and LAI were increased up to 22 and 44Kg P/ha respectively, LAR and

NAR were hot affected by P levels. Maximum concentration of N in both shoot and fruit were attained at 22KgP/ha. The rate also resulted in the lowest concentration of P and K. Neither the concentration of Ca and Mg in the shoot nor in the fruit were affeced by applied P. Both flowering and maturity were hastened with P addition. Fruit size was generally not influenced by applied P.

Transplanting at the density of 20,000 plants/ha yielded superior partitioned aerial phytomoss and LAR compared with 60,000 plants/ha LAI, RGR and NAR were however increased with increasing plant density up to 60,000 plants/ha. Flowering, fruit maturity and size were not significantly affected by the three densities tested. Inspite of the fact that fruit and seed yield/plant were depressed by high population densities, yield/ha was increased significantly at higher densities.

Significant interactions between the factors were recorded on some of the parameters studied.

Regression analysis indicated optimum N concentration in shoot at a range of 130-270KgN/ha. P concentration in shoot showed a quadratic response to N and P levels.

Result of correlations and path analysis showed positive and highly significant association between yield and virtually all other' parameters tested. Indirect contribution of most characters to yield was greatest through total dry weight, number and diameter of fruits and seed yield.

Using regression constants, cost and returns of inputs and output, optimum levels of nutrients were found to be 140KgN/ha, 25KgP/ha for fruit production and 202KgN/ha, 20KgP/ha for seed production while the plant density of 60,000 plants/ha was optimum for both fruit and seed yield.

CONTENTS

		Page
	Title page	i
	Declaration	ii
	Certification	iii
	Dedication	iv
	Acknowledgements	v
	Abstract	vii
	Contents	x
	List of Tables	xvi
	List of figures	xxi
	List of Appendices	xxiii
	Abbreviations	xxiv
1.0	INTRODUCTION	1
2.0	LITERATURE REVIEW	4
2.1	Climatic and Soil Conditions of the Nigerian Savanna	4
2.2	Fertilizer Ue in Nigeria	6
2.3	Effect of Nitrogen on the Gowth and yield of Pepper	7
2.4	Effect of phosphorus on the Growth and yield of pepper	10
2.5	Interaction of N and P on the Growth and yield of pepper	12

2.6 Effect of Plant Density on the Growth and yield of pepper 15

2.7 Nutrient Content of Plant Tissue as affected by Nitrogen and phosphorus levels 17

2.8 Growth and Yield of Pepper as affected by nutrients x plant density interaction 18

3.0 MATERIALS AND METHODS

3.1 Experimental Site 21

3.2 Crop Rotation 21

3.3 Crop Variety 22

3.4 Experimental Details..... 22

3.5 Cultural Practices 23

3.5.1 Nursery management..... 23

3.5.2 Land preparation 23

3.5.3 Transplanting 23

3.5.4 Pests and disease control 23

3.5.5 Harvesting 24

3.6. Meteorological Data 24

3.7 Crop data 24

3.7.1 Plant height 25

3.7.2 Number of branches 25

3.7.3 Number of leaves 25

3.7.4 Dry aerial phytomass 25

3.7.5 Leaf Area 25

3.7.6 Leaf area index 25
3.7.7 Leaf area ratio 26
3.7.8 Relative growth rate 26
3.7.9 Net assimilation rate 26
3.7.10 Nutrient composition and uptake 27
3.7.11 Number of days to 50% flowering 27
3.7.12 Number of days to ripeness/maturity 27
3.7.13 Fruit length 27
3.7.14 Fruit diameter 27
3.7.15 Fresh fruit yield/plant 27
3.7.16 Fruit dry yield/plant 27
3.7.17 Number of fruits/plant 28
3.7.18 Fresh fruit yield/ha 28
3.7.19 Dry fruit yield/ha 28
3.7.20 Number of seeds/fruit 28
3.7.21 Number of seeds/plant 28
3.7.22 Seed yield/plant 28
3.7.23 Seed yield/ha 28
3.8 Analytical Procedures 28
3.8.1 Soil analysis 28
3.8.2 Plant tissue analysis 29
3.9 Statistical Analysis 30
3.10 Economic Analysis 31
3.11 Optimum Levels of Nutrients 31

4.0 RESULTS

4.1 Influence of Nitrogen and Phosphorous Levels and Plant Density on the Growth of Pepper..... 32

4.1.1 Plant height 32

4.1.2 Number of branches/plant 35

4.1.3 Number of leaves/plant 37

4.1.4 Leaf dry weight 41

4.1.5 Stem dry weight 42

4.1.6 Dry weights of buds, flowers and fruits, ... 43

4.1.7 Total dry weight/plant 50

4.1.8 Leaf area/plant 55

4.1.9 Leaf area index 59

4.1.10 Leaf area ratio 65

4.1.11 Relative growth rate 69

4.1.12 Net assimilation rate 74

4.2 Nutrient concentration in Shoot as influenced by Nitrogen and Phosophorous Levels 78

4.2.1 Nitrogen 78

4.2.2 Phosphorus 81

4.2.3 Potassium 83

4.2.4 Calcium 83

4.2.5 Magnesium 86

4.3 Effect of Nitrogen and Phosphorus Levels on Nutrient Concentration in Fruit 87

4.4 Nutrient Uptake as Influenced by Nitrogen and Phosphorous levels 89

4.5 Yield Components as affected by Nitrogen and Phosphorus Levels and Plant Density 93

4.5.1 Number of days to 50% flowering 93

4.5.2 Number of days to maturity 95

4.5.3 Fruit length 95

4.5.4 Fruit diameter 98

4.5.5 Number of fruits/plant 98

4.5.6 Number of seeds/fruit 103

4.5.7 Number of seeds/plant 104

4.6 Influence of Nitrogen and Phosphorus levels and Plant Density on the Yield of Pepper..... 107

4.6.1 Fresh fruit yield/plant 107

4.6.2 Fresh fruit yield/ha..... 109

4.6.3 Dry fruit yield/plant..... 110

4.6.4 Dry fruit yield/ha 114

4.6.5 Seed yield/plant 116

4.6.6 Seed yield/plant/ha 117

4.7 Regression Analysis 120

4.7.1 Fruit yield Vs. levels of nitrogen, phosphorus and plant density 120

4.7.2 Seed yield Vs. levels of nitrogen, phosphorus and plant density 120

4.7.3 Fresh fruit yield/ha Vs. concentrations of nitrogen and phosphorus in shoot 122

4.7.4 Nitrogen concentration in shoot Vs. level of nitrogen and phosphorus 122

4.7.5 Phosphorous concentration in shoot Vs levels of nitrogen and phosphorus 126

4.8 Correlations and Path-Coefficient Analysis ... 128

4.8.1 1991: Yield and yield component characters .. 128

4.8.2 1992: Growth, yield and yield component characters 131

4.8.3 1993: Growth, yield and yield component characters 138

4.8.4 Nutrient concentration and uptake 145

4.9 Economic Analysis..... 148

4.10 Optimum Level of Nutrients 148

5.0 DISCUSSION

5.1 Effect of Season 152

5.2 Response to Nitrogen 154

5.3 Response to Phosphorous 159

5.4 Response to Plant Density 164

5.5 Interactions 166

5.5.1 Nitrogenx phosphorus interaction 166

5.5.2 Nutrients x plant density interaction 167

5.6 Regression Analysis 167

5.7 Correlation and Path-coefficient Analysis 168

5.8 Economic Analysis 169

5.9 Optimum Level of Factors 169

SUMMARY AND CONCLUSION 171

References 174

Appendices 187

Biography 191

LIST OF TABLES

Table		Page
1.	Interaction between Nitrogen and plant density on plant height in 1992	36
2.	Plant height (cm) at 10WAT as affected by nitrogen and phosphorus interaction, 1992	36
3.	Interaction between nitrogen and plant density on leaf dry weight (g) at 8WAT in 1992	48
4.	Stem dry weight (g) at 4WAT as influenced by nitrogen x plant density in 1991, ...	48
5.	Stem dry weight(g) at 6WAT as influenced by nitrogen x phosphorus in 1991	49
6.	Stem dry weight(g) at 4WAT as affected by phosphorus x plant density in 1991, ...	49
7.	Effect of nitrogen, and phosphorus levels and plant density on total dry weight(g) in 1991, ...	51
8.	Interaction between nitrogen and plant density on total dry weight(g) at 4WAT in 1991.	52
9.	Effect of nitrogen and phosphorus levels and plant density on total dry weight(g) at different sampling periods in 1992.	53
10.	Effect of nitrogen and phosphorus levels and plant density on total dry weight(g) at different sampling periods in 1993..... ...	54
11.	Effect of nitrogen and phosphorus levels and plant density on leaf area/plant (cm^2) at various sampling periods in 1991.....	56
12.	Effect of nitrogen, phosphorus levels and plant density on leaf area/plant (cm^2) at various sampling periods in 1992.	57

13. Effect of nitrogen and phosphorus levels and plant density on leaf area/plant (cm^2) at various sampling periods in 1993..... 53

14. Leaf area index as influenced by nitrogen and phosphorus levels and plant density at different periods in 1991. 61

15. Interaction between nitrogen and plant density on leaf area index at 10WAT in 1991. 62

16. Leaf area index as influenced by nitrogen and phosphorus levels, and plant density at different periods in 1992. 63

17. Leaf area index as influenced by nitrogen and phosphorus levels and plant density at different periods in 1993. 64

18. Leaf area ratio (cm^2/g) as influenced by nitrogen and phosphorus levels and plant density at various sampling periods in 1991,... 66

19. Leaf area ratio (cm^2/g) as influenced by nitrogen and phosphorus levels and plant density at various sampling period in 1992,... 67

20. Leaf area ratio (cm^2/g) as influenced by nitrogen and phosphorus levels and plant density at various sampling periods in 1993. ... 68

21. Relative growth rate (g/g/day) as influenced by nitrogen and phosphorus levels and plant density at various sampling periods in 1991.... 71

22. Relative growth rate (g/g/day) as influenced by nitrogen and phosphorus levels and plant density at various sampling periods in 1992. .. 22

23. Relative growth rate (g/g/day) as influenced by nitrogen and phosphorus levels and plant density at various sampling periods in 1993. .. 7

24. Net assimilation rate ($g/cm^2/day$) as influenced by nitrogen and phosphorous levels and plant density at various sampling periods in 1991, Samaru..... 75

25. Net assimilation rate (g/cm^2/day) as influenced by nitrogen and phosphorus levels and plant density at various sampling period in 1992. ... 76

26. Net assimilation rate (g/cm^2/day) as influenced by nitrogen and phosphorus levelsand plant density at various sampling periods in 1993. ... 77

27. Nitrogen concentration in shoot (%) as affected by nitrogen and phosphorus levels at different periods in 1992 and 1993..... 79

28. Interaction between nitrogen and phosphorus on nitrogen concentration in shoot (%) in 1992 80

29. Phosphorus concentration in shoot (%) as affected by nitrogen and phosphorous levels at different periods in 1992 and 1993..... 82

30. Interaction between nitrogen and phosphorus on phosphorus concentration in shoot (%) at 8 and 12WAT in 1992..... 82

31. Potassium concentration in shoot (%) as influenced by nitrogen and phosphorus levels at 8 and 12WAT in 1992 and 1993, ... 84

32. Calcium concentration in shoot (%) as affected by nitrogen and phosphorus levels at 8 and 12WAT in 1992 and 1993, ... 85

33. Magnesium concentration in shoot (%) as affected by nitrogen and phosphorus levels at 8 and 12WAT in 1992 and 1993, ... 86

34. Nutrient concentration (%) in pepper fruits at 14WAT as affected by nitrogen and phosphorus levels in 1992..... 88

35. Nitrogen x phosphorus as it affected nutrient concentration (%) in pepper fruits at 14WAT in 1992 91

36. Nutrient uptake (g/plant) as influenced by nitrogen and phophorus level at 12WAT in 1993..... 92

37. Interaction between Nitrogen and Phosphorus Nutrient Uptake (g/plant) at 12WAT in 1993..... 92

38. Effect of nitrogen, and Phosphorus levels and plant density on number of fruits/plant..... 101

39. Number of fruits/plant as affected by nitrogen x plant density interaction in 1992 and 1993..... 102

40. Number of fruits/plant as affected by nitrogen x phosphorus interaction in 1993,..... 103

41. Number of seeds/fruit as influenced by nitrogen and phosphorus levels and plant density 105

42. Number of seeds/plant as influenced by nitrogen and phosphorous levels and plant density. 106

43. Fresh fruit yield (g/plant) as influenced by nitrogen and phosphorus levels and plant density 108

44. Fresh fruit yield (tons/ha) as influenced by nitrogen and phosphorus levels and plant density 111

45. Fresh fruit yield (tons/ha) as influenced by nitrogen x plant density in 1992, ... 112

46. Fresh fruit yield (tons/ha) as influenced by plant density x phosphorus in 1992..... 112

47. Dry fruit yield (g/plant) as influenced by nitrogen and phosphorus levels and plant density..... 113

48. Dry fruit yield (tons/ha) as influenced by nitrogen and phosphorus levels and plant density 115

49. Dry fruit yield (tons/ha) as influenced by nitrogen x plant density in 1992 and 1993. 116

50. Seed yield (g/plant) as influenced by nitrogen and phosphorus levels and plant density, Samaru 118

51. Seed yield (kg/ha) as influenced by nitrogen and phosphorus levels and plant density..... 119

52. Matrix of correlation between yield and some yield component characters in 1991. 129

53. The direct and indirect contributions of different characters on fresh yield in 1991. 131

54. Matrix of correlation between some growth and yield characters in 1992. 132

55. The direct and indirect contributions of different growth characters on fresh fruit yield in 1992 135

56. Matrix of correlation between yield and some yield component characters in 1992. 136

57. The direct and indirect contributions of different yield component characters on fresh fruit yield in 1992..... 138

58. Matrix of coefficients betweensome growth and yield characters in 1993..... 140

59. The direct and indirect contributions of different growth characters on yield in 1993..... 142

60. Matrix of correlation between yield and some yield component characters in 1993..... 143

61. The direct and indirect contributions of some yield component characters on fresh fruit yield in 1993 145

62. Matrix of correlation between nutrient concentration in shoot in 1992..... 146

63. Matrix of correlation between nutrient concentration in shoot in 1993..... 147

64. Matrix of correlation coefficients between uptake of various nutrients in 1993..... 147

65. Labour rates and costs in pepper production 150

66. Cost and returns from pepper production with various nitrogen and phosphorous levels (Pooled data for 1991 to 1993) 151

LIST OF FIGURES

Figure		Page
1.	Height of pepper plants as influenced by nitrogen and phosphorus levels and plant density in 1991-93 at various sampling periods ..	34
2.	Number of branches as affected by nitrogen and phosphorus levels and plant density in 1991-93 at various growth stages	38
3.	Number of leaves as affected by nitrogen and phosphorus levels and plant density in 1991-93 at various periods	40
4.	Cumulative dry matter partitioning as affected by nitrogen levels	45
5.	Cumulative dry matter partitioning as affected by phosphorus levels	46
6.	Cumulative dry matter partitioning as influenced by plant density	47
7.	Effect of nitrogen and phosphorus levels and plant density on days to 50% flowering in pepper..	94
8.	Effect of nitrogen and phosphorus levels and plant density on days to maturity in pepper	96
9.	Effect of nitrogen and phosphorus levels and plant density on fruit length in pepper	97
10.	Effect of nitrogen and phosphorus levels and plant density on fruit diameter in pepper	99
11.	Regression of fresh yield on nitrogen, phosophorus levels and plant density	121
12.	Regression of seed yield on nitrogen and phosphorus levels and plant density	123
13.	Regression of fresh fruit yield on nitrogen and phosphorus concentration in shoot	124

14. Regression of nitrogen concentration in shoot on nitrogen and phosphorus levels 125

15. Regression of phosphorus concentration in shoot on nitrogen and phosphorous levels 127

16. A path diagram showing relationships between yield and some yield components in 1991 130

17. A path diagram showing relationships between yield and some growth characters in 1992 134

18. A path diagram showing relationship between yield and some yield components in 1992..... 137

19. A path diagram showing relationships between yield and some growth characters in 1993 141

20. A path diagram showing relationships between yield and some yield components in 1993..... 144

LIST OF APPENDICES

Appendix		Page
1.	Samaru meteorological observations in 1991 ..	187
2.	Samaru meteorological observations in 1992 ...	188
3.	Samaru meteorological observations in 1993 ...	189
4.	Physico-chemical properties of the soil at the site of the experiments, Samaru	190

ABBREVIATIONS AND SYMBOLS

g	Gram
Kg	Kilogram
Mg	Milligram
Ml	Millilitre
l	litre
Meq	Milliequivalent
M	Meter
m^2	meter squared
Cm	Centimeter squared
mm	Millimeter
ha	Hectare
%	Percentage
WAT	Weeks after transplanting
ppm	Parts per million
C.E.C	Cation Exchange capacity
N	Nitrogen
P	Phosphorous
K	Potassium
Ca	Calcium
Mg	Magnesium
H	Hydrogen
Al	Aluminium
Na	Sodium
Am	ante meridiem (beforenoon)
Pm	Post meridiem (afternoon)

Min.	Minimum
Max	Maximum
LAI	Leaf area index
LAR	Leaf area ratio
RGR	Relative growth rate
NAR	Net assimilation rate
NS	Non significant difference
*	Significant difference at 5% level
**	Significant difference at 1% level
Y	Predicted dependent variable
r	Simple correlation coefficient
R^2	Coefficient of determination
x	Independent variable
oC	Degree centigrade
Lat.	Latitude
/	per
SE	Standard error
W	Total dry weight
A	Leaf Area
L	Leaf Area
t	time.

CHAPTER ONE

1.0 INTRODUCTION

Pepper (Capsicum annuum L.) a crop of tremendous economic and nutritional importance in Nigeria, has been an important export crop in the country. Nigeria, which is the largest producer of the crop in Africa, accounts for about 50% of the African production. The consumption of pepper accounts for about 20 - 40% of the total vegetable consumed per person per day. The tendency to eat more vegetables than starchy staples, the general increase in the standard of living, coupled with increasing consumer population have placed demands on vegetables that are not commensurate with the supply. Deregulation of the Nigerian economy and the export promotion campaign have led to the development of fresh vegetable export companies and processing factories thereby adding to the demand for pepper. Thus, the ever increasing demand for pepper could not be sustained by the present low production level which was brought about largely due to the use of inadequate plant density, and nutrients supply during production.

The use of adequate levels of nutrients is important in increasing the production and yield of pepper in Nigeria.

This is more so as the nutrient status of savanna soils is generally low especially with respect to nitrogen and phosphorus. Crops however respond to fertilization in these soils because of their favourable base exchange properties. However because the buffering capacity of Nigerian savanna soils is low, the use of mineral fertilizers on a continuous basis and in substantial quantities leads to a gradual replacement of Ca, and K by Al and H ions in the exchange complex. This has a drastic effect on soil PH which declines rapidly with time and further increases soil acidity. The analysis of experimental results have also indicated that crop response to fertilizers may be subject to the law of diminishing returns, that is, there may be a continuous decrease in yield increments with increasing fertilizer dressings by successive identical amounts. It is therefore pertinent to evaluate the effect of nitrogen and phosphorous fertilization on the productivity of pepper plant in the savanna agro-ecological zone, the major area of production of the crop.

The use of optimum planting density is another pre-requisite to increasing the per hectare yield of pepper. Pepper plants are generally inefficient when grown at sub-optimum densities and consequently, aggregate yield of pepper is usually low despite high productivity per plant. This is because pepper plants under-utilize environmental resources such as radiant energy, soil nutrients and moisture.

Inadequate stand also suppresses weeds poorly and the crop being a poor competitor with weeds, weed growth can severely reduce its potential yield. Investigations were therefore conducted with the following objectives.

(1) To study the effect of nitrogen and phosphorus levels on the growth and yield of pepper.

(2) To study the influence of plant density on the growth and yield of pepper.

(3) To examine the mineral composition and uptake in pepper as affected by nitrogen and phosphorus levels.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Climate and Soil Conditions of the Nigerian Savanna

The savanna ecological zone of Nigeria extends from latitude 7^0N to 14^0N covering about four - fifths of the country's total land area. The zone is sub-divided into four agro-climatic areas. The Sahel zone (Lat. 12^0 - 14^0N), the Sudan zone (Lat. 10^0 - 13^0N), the Guinea savanna (7^0 - 10^0N) is further divided into the Northern Guinea and the Southern Guinea (Keay, 1959) Nigeria's savanna is characterized by distinct wet and dry seasons with the length of the rainy season decreasing northwards from about seven to eight months in the Southern Guinea savanna to less than 90 days in the Sudan/Sahel zone. The total rainfall also decreases northwards from about 1,600 - 1,800 mm in the Southern Guinea Savanna to less than 500 mm in the extreme north of the country. Incoming solar radiation is generally high with mean air temperature ranging from 21 - 30^0c (Owonubi and Yayock, 1987).

As with most lands within the tropical latitudes, there are considerable micro and macro-variabilities in the types of soils found in the Nigerian savanna (Klinkenberg and Higgins, 1968). However, the four major types are Alfisols which are the most dominant, Inceptisols, Entisols and Vertisols

(Lombin, 1987). The Alfisols, Entisols and Inceptisols together dominate the area and are characteristically sandy soils derived mainly from aeolian deposits. They are generally mildly to medium acid with PH (H_2O) usually ranging from about 5.5 to near 7.0. They are low in organic matter (often less than 2%) low in CEC (often less than 5 meq/100g), generally poorly buffered and poorly structured (Jones and Wild,1975). Vertisols which constitute only about 2% of the soil resources of the area are mostly derived from calcareous materials. They are generally dark-coloured expansible clays high in exchangeable bases but low in organic matter (Klingkenberg and Higgins, 1968).

The alternating wet and dry seasons characterized by intense heat during the dry season may lead to rapid decomposition of soil organic matter. Indiscriminate burning of fallow and crop residues by farmers also reduces the accumulation of organic matter in the soil. Thus the soils rapidly lose their fertility and productivity under cultivation (Jones, 1971). One way of maintaining productivity is by the use of fertilizers supplemented with organic manure. However due to low buffer capacities, it is relatively easy to cause ionic imbalance and acidity by incorrect use of fertilizers (Lombin 1981).

Because soil organic matter is low, native soil nitrogen is also very low (Jones, 1973). Phosphorus and sulphur deficiencies are also wide spread (Goldsworthy and Heathcote,

1963) Potassium, calcium and magnesium deficiencies are not common (Wild, 1971; Jones and Wild, 1975). Micronutrient levels in these soils are still fairly high (Heathcote and Stocking 1970). Subsequently, much of the fertilizer recommendation for crops in the savanna zone have bean confined to the two most limiting elements (nitrogen and phosphorus).

2.2 Fertilizer Use in Nigeria

The Agricultural value of farmyard manure (FYM), including poultry dropping, dung and household refuse was brought into eminence since the late 1940's (Abdullahi and Lombin, 1978). However, enough farm yard manure could not be obtained to sustain agricultural productivity due to the intensification of Nigerian agriculture coupled with the introduction of higher yielding and more nutrient demanding crop varieties. Even where available, transportation problem and labour costs limited the use on a routine basis (Enwezor, et al, 1989). Under such a situation, the focus was turned to inorganic fertilizers as the alternative.

The first reports on the potential value of fertilizers in Nigeria were made by Hartley (1937), Doyne (1937) and Buckly (1938). These infact, mark the beginning of chemical fertilizer consumption in Nigeria. When they were first introduced, fertilizers were given out to farmers almost free. In most cases only innovative farmers were willing to use them, while the generality of farmers showed a marked apathy

towards the use of fertilizers. Tremendous energy and effort has been expended over the years by the government to get the Nigerian farmer to accept and use mineral fertilizers.

A fertilizer consumption survey carried out by the Federal Department of Agriculture showed a remarkable upward trend in fertilizer consumption between 1969 when 28,699 tones were used and 1972 when 71,290.6 tons were applied by the Nigerian farmers (Mokwuenye,1974A), and the consumption in 1986 was as much as 589,000 tons (Falusi, 1987). In 1969, only 10 percent of the minimum fertilizer required per hectare was actually applied. In that year an average of 4.95 kg/ha was applied to the main crops. Inspite of the steep increase in the use of fertilizers, Nigeria's position as a country with very low levels of fertilizer use has not altered. As at 1979, consumption of plant nutrients in Nigeria was put at 3.11 kg/ha compared to about 740 kg/ha in the Netherlands and average of 250 kg/ha in several European countries and was far less than the world average of 68 kg/ha (Sobulo and Osiname, 1985). The estimated consumption of 8.7 kg/ha in 1983/84 was about 10 percent of the world's average and about 20 percent of Indian consumption level (Falusi, 1987). These comparative figures are indicative of the need as well as the tremendous scope for increasing the use of mineral fertilizers.

2.3 Effect of Nitrogen on the Growth and Yield of Pepper

Nitrogen (N) is the most limiting factor for production of crops on tropical soils. This is because tropical soils

are low in native nitrogen, while the amount removed by crops is comparatively large. Due to its readily soluble nature, nitrogen is easily lost in drainage or get converted to gaseous form and is lost through volatilization. Of the essential elements, nitrogen exerts the most pronounced effect on plant growth and yield. Apart from its role in the synthesis of proteins, nitrogen is a constituent of enzymes and is an integral part of the chlorophyll molecule. It is therefore involved in all processes associated with protoplasm, enzyme reactions and photosynthesis.

As nitrogen rates applied to pepper plants are increased plant growth, fruit set and yield are also increased (Wien et al, 1989). At high rates of nitrogen, (300-400kg N/ha) some workers have found that yields again declined (Knavel, 1977; 'O' Sullivan, 1979; Locascio et al, 1981) while others noted only a levelling off of yield (Maynard et al 1962 Batal and Smittle, 1981). Wien et al (1989) ascribed the differences in results obtained by different researchers to variation in amounts of N applied, soil types on which the experiments were conducted, and rainfall obtained during the growing season. Leaf colour, plant vigour and plant height were directly related to N levels (Maynard et al, 1962). Pepper has been reported to produce high percent of blossoms on receiving high nitrogen levels when compared with low levels. Such plants also exhibit longer leaf retention and lower flower and fruit abortion (Addicot and Lynch, 1955). Nitrogen application has

also been reported to increase number of branches per plant and seed yield (Gill et al. 1974), number of shoots, fruits per plant and the weight of 100 fruits generally increase with rising nitrogen levels up to 160 kg N/ha. (Ramachandran and Subhail, 1987). Fruit yield has been shown to be positively correlated with most growth parameters such as plant height, number of leaves and branches (Ado, 1983; 1987; Aliyu et al. 1991). Thus, inputs that have a positive influence on these parameters like nitrogen fertilization will greatly enhance fruit yield.

Covarelli (1976), Dharmatti and Kulkarni (1988) reported an increase in weight and number of fruits at 200 kg N/ha. However, Lal and Pundric (1971) obtained the highest yield of chilli pepper at a much lower level of 140 kg N/ha. Locascio et al. (1981) reported that application of nitrogen in excess of 134 kg N/ha reduced the yield of pepper whilst Jones et al, (1964) reported yield decrease with N above 120 kg N/ha. Ozaki and Ray (1967) however, reported a reduction in yield only when 400 kg N/ha was applied. Payero et al. (1981) reported that 240 kg N/ha is the best for optimum yields. Most vegetable crops require a continuous supply of nitrogen for maximum yield and quality, nitrogen rates of 300 - 400 kg N/ha are therefore not uncommon (Govind, 1979). In chilli pepper moderate rates of 100 - 190 kg N/ha tended to produce more desirable type of plants and highest yield (Stroelilein, 1979). Bajaj (1970) similarly reported application of 100 kg

N/ha to give maximum, protein, ascorbic -acid and capsaicin contents in pepper fruits.

Economic use of nitrogenous fertilizer also requires a good understanding of its total requirement by the crop as well as identifying the time of its peak requirement during the growing season. Sinha (1979) recorded the highest yield by applying 190 kg N/ha at transplanting and also at fruiting. In contrast, the yield was not affected when 33 kg N/ha was applied as a top dressing after transplanting the crop (Stambera and Petrikova, 1976). Cultural practices such as mulching have also been reported to influence the response of pepper to nitrogen application. Locascio and Fiskell (1977) reported an increase in fruit yield with rising nitrogen up to 224 kg N/ha when polyethylene mulch was used.

Trials at Samaru have shown that fruit yield, number of leaves and fruits were significantly increased with increase in nitrogen levels up to 300 kg N/ha (Isma, 1989; Aliyu et al 1994). Usman (1990) also reported increases in plant height, number of leaves, branches and fruits, leaf area index and fruit yield with rising nitrogen levels up to 190 kg N/ha in chilli pepper. However, Aliyu and Yusuf (1991) could not detect any difference in fruit yield, fruit diameter and number of fruits when nitrogen rate was increased from 120 kg N/ha to 180 kg N/ha.

2.4 Effect of Phosphorus on the Growth and Yield of Pepper

Next to nitrogen, phosphorus is the second important

limiting nutrient in most agricultural soils. Deficiency of phosphorus is particularly common in highly weathered Oxisols and Ultisols of the tropics notably in the Savanna areas with low organic matter contents (Bache and Rogers, 1970; Mokwuenye, 1974b). The external phosphorus requirement of numerous crops have been found to be within a range of 0.01 - 0.4 ppm P in solution (Fox, 1979). The requirement however, seems to increase with increasing yield potential. In savanna soils, total phosphorus ranges from a mean of less than 100 ppm to more than 400 ppm; while the water - extractable P is less than 0.2 ppm and most crops will produce only meager yields in the absence of phosphate fertilizers (Udo and Ogunwale, 1977; Mokwuenye, 1979).

The effect of phosphorus on crop growth is generally seen in earliness to maturity and enhanced root system. Phosphorous is a constituent of cell nuclei and is essential for cell division and enlargement. Phosphorus is also required in photosynthesis, respiration and energy storage. Nutrient absorption and metabolism are also phosphorus dependent (Brady, 1978; Mengel and Kirkby, 1982). Pepper plants receiving very low P have been reported to produce narrow leaves that are glossy and developed a greyish green colour with weak growth (Miller, 1961).

Unlike nitrogen, very little information is available on the effect of phosphorus on the performance of pepper especially in the Nigerian savanna. Elsewhere,

phosphorusapplication up to 109.25 kg P/ha has been reported to result in increased number of fruits while number of days to flowering decreased (Gill et al, 1974). A single broadcast application of 246.62 kg P/ha has also been reported to increase plant growth and yield for two crop seasons when compared with lower rates (Ozaki and Key, 1966). Plant height and yield have been reported to increase with the addition of 21.89 kg P/ha (Damke et al, 1988). Bajaj (1970) obtained maximum protein, ascorbic acid and capsaicin content at 48 kg P/ha while Stroelilein (1979) could not detect any yield difference due to phosphorous application. Olarewaju (1977) working at Samaru and Sagiv and Kafkafi (1976) similarly reported that phosphorous applied at 158 kg P/ha had no significant effect on the total number of fruits and fruit yield. Application of 33.63 kg P/ha also did not significantly increase the yield and nutrient concentration of pepper (Jones et al, 1964). However, Muhammad (1989) also working at Samaru obtained increases in number of branches, and leaves, plant height and leaf area index with the application of 17.48 kg P/ha. Increasing the rate to 34.96 kg P/ha resulted in fruit yield increase in chilli pepper.

2.5 Interaction of N and P on the Growth and Yield of Pepper

Plant nutrients are generally complementary in their action. The availability of certain nutrients may improve the uptake and utilization of others. Nitrogen and phosphorus are both essential for plant growth and a deficiency of either

will limit the growth of root and tops. Stimulation of plant growth by nitrogen may be expected to increase the demand for phosphorous, but nitrogen also stimulates the plant in a way which increases its ability to take up P. Positive interactions between nitrogen and phosphorus fertilizers have been reported to occur quite often especially when the two are applied together, although the mechanisms involved are still in doubt (Gunes, 1959). He reported nitrogen application to increase the absorption of phosphorus and he attributed this phenomenon to increased growth of roots and tops which consequently improved the uptake of phosphorus. Several workers have also reported the existence of interaction between nitrogen and phosphorus on different characters notably crop yield (Dennison, 1961, Cope and Hunter, 1967) but these have generally resulted from a simple interaction in which the application of a previously deficient nutrient which limited growth permitted the crop to respond to the other.

Nitrogen x phosphorus interaction occurs in several ways. Balasubramanian et al. (1979) reported that deficiency of phosphorous retards nitrification in the soil and therefore, leads to low efficiency of applied ammonium nitrogen fertilizers. Nye (1952) found that the interaction between nitrogen and phosphorus was highly positive whenever the effect of individual element was high. However, Zayeed et al. (1985) reported that nitrogen and phosphorous at high rates increased plant height, plant dry weight, fruit number and

total yield. The beneficial effects of combined nitrogen and phosphorus fertilization has been explained on the basis of:

1) soil chemical interactions between nitrogen and phosphorous which may influence phosphorus availability and in special cases nitrogen availability, and
2) plant physiological interactions between nitrogen and phosphorus which may influence plant phosphorus uptake and some times dry matter yield.

Reviews by Olsen (1953),and Gunes (1959), emphasize the varied effects of nitrogen especially upon the solubility and availability of phosphatic compounds in the soil. This is mostly through phosphate solubility and mobility.

The most likely explanation of the beneficial effects of nitrogen salts is through an increase of the solubility of the phosphate compounds or their reaction products. Gunes (1959) stressed the importance of phosphorus mobility in placement effects. When nitrogen and phosphorus are placed together in low phosphorous soils, much of the increased phosphorus up take comes from the fertilized zone. Nitrogen did not increase phosphorus uptake in the absence of a phosphorus fertilizer source. Whereas phosphate influence nitrogen availability through stimulation of organism responsible for breaking down organic matter in reducing ammonia by reaction of hydrogen ion from single super phosphate with ammonium to give ammonium phosphate (Stephen and Waid, 1963) and by improving nitrogen fixation (Dhar and Banerjee 1961).

Growth, yield and quality of pepper have been reported to be significantly affected by an interaction between nitrogen and phosphorus. Fruit quality was significantly improved by a combination of 100 kg N/ha and 48 kg P/ha (Bajaj, 1970). Combined application of 190 kg N/ha and 34.96 kg P/ha was also reported to result in significantly more fruits and higher fruit yield than other combinations (Muhammad. 1989). 120 kg N/ha and 26.22 kg P/ha resulted in maximum yield biologically and economically (Kulvinder and Shrivastava 1988). Eguchi et al (1958) and Uzo (1971) reported a delay in enthesis when nitrogen alone was supplied. However, flowering was early when phosphorus was applied in conjuction with nitrogen or a combined NPK was used.

2.6 Effect of Plant Density on the Growth and Yield of Pepper

Pepper is generally grown in mixture with other crops under the traditional farming system adopted by the peasant farmers (Okigbo, 1975; Okigbo and Greenland, 1976). However a negative yield relationship between pepper and maize grown in mixture compared to sole pepper has been reported (Yunana, 1982). Wiley (1979) attributed this decrease in yield to adverse competitive effects, allelopathic effects and difficulties concerned with practical management of mixtures. Kass (1978), therefore, suggested that mixed cropping of pepper should be replaced with sole cropping. A practice which is becoming popular with farmers as a result of change in the traditional farming system associated with increasing

population pressure on land and the introduction of new crops and farming techniques (Usman, 1990).

Several workers from different parts of the World have investigated the effect of plant density on sole pepper. Silva and Couto (1971) reported that too much crowding of plants might adversely affect the yield or at least depress the fruit weight. Dempsey (1970), similarly reported that high plant density caused a significant reduction in stem diameter and a reduction in plant height. Mezhunts (1979) found that high plant density reduced leaf size and number and diminished dry weights. Ramachandran and Subhail (1987) reported decreased number of shoots and fruits/plant with increased plant density and obtained highest yield of fruits from a population of 166,667 plants/ha. Yanateva and Elogin (1977) attributed yield reduction per plant at high plant densities to photosynthetic insufficiency. This observation seems to confirm that of Topoleski (1967) who also attributed yield reduction per plant in densely populated plants to competition between plants for water, nutrients and sunlight.

Jessup (1964) recommended a range of 20,768 to 29,240 plants/ha as the optimum population density for growing Capsicums and reported that attempts to increase fruit yield by raising plant population have not given clear, consistent results. Similarly, Metwally et al. (1982) did not observe any difference in number of branches per plant and plant height due to planting density, the yield and number of fruits

were however, significantly increased at the highest density of 55,555 plants/ha. Rastogi et al. (1980) also obtained the highest yield at the density of 49,000 plants/ha when compared with lower plant populations. In another trial on pepper grown at 27,000; 55,000 and 110,000 plants/ha; yields were reported to increase with increase in plant populations and the greatest dry biomass was produced at the highest density (Strelec and Duda 1981). Boominathan et al.(1971) similarly found that planting pepper at 111,111 plants/ha out yielded those planted at 74,074 plants per hectare by 21%. Patil and Vijay (1979) also recorded significant increase in yield when the density was increased from 37,037 to 111,111 plants/ha. Densities of 56,000 plants/ha and 83,000 plants/ha were also found to give the highest yield at two respective locations (Yosef and Yayeh, 1988). A population as high as 250,000 plants/ha has also been reported to give the best yield when compared with 166,667 and 62,500 plants/ha (Sinha, 1975).

At Samaru, the highest density of 44,444 plants/ha decreased the growth and yield/plant in chilli whereas the total yield/ha was significantly increased when compared with lower populations of 33,333 and 26,667 plants/ha (Aliyu and Yusuf,1991). When plant density was increased to 100,000 plants/ha the total yield/ha was not significantly improved compared to lower plant densities (Aliyu et al 1994).

2.7 Nutrient Content of Plant Tissue as Affected by Nitrogen and Phosphorous Levels.

Traditionally fertilizer needs are estimated from field experiments and such estimations are helpful when the intention is to predict the amounts of nutrients required for a certain crop at the locality chosen. However, no generalized conclusion can be deduced from the results obtained.

Another method used for estimating the fertilizer requirement is soil analysis. Through chemical analysis of the soil a determination is made of the amount of nutrients available for the crop. One of the disadvantage is to extract the nutrients to the same extent as they are absorbed by the plant. Chemical analysis of the plant may give a more accurate information on the actual mineral uptake by the plant. Analysis of the plant to uncover the relationship between the nutrient supply and the chemical composition of the plant was first made by de Saussure (1804), followed by Emmert (1939, 1941); Goodall and Gregory (1947), Ulrich (1952), Smith (1962).

Application of nitrogen has been reported to significantly increase leaf tissue N (Jones et al 1964; Stroelilien, 1979) and decrease P content whilst P levels had no significant effect on N and P content of foliage (Jones et al, 1964). They also found that neither N nor P levels in the fruits were affected by the fertilizer addition. Maynard et al (1962) however, reported that both fruit and leaf N increased with N levels up to the highest level (400 ppm).

Visual deficiency symptoms have been reported to occur in plants having a total N content of 1.26% or less in vegetative tissue (Miller, 1961). Uzo (1976) reported that percentage P content was a positive function of both the rate of P applied and the method of application. Johansson (1978), reported that the elemental contents of the nutrient solutions were reflected in the chemical composition of the leaves as well as in that of the wood, low N supply increased the ash and Ca content of the leaves and at low P the N content decreased.

Experimental results reviewed by Epstein and Jefferies (1964) indicate that the level of selectivity in nutrient uptake, translocation and utilization of nutrients by plants are genetically controlled. It was stressed that the efficiency by which a crop utilizes soil as a source of nutrients is improved if genotypes with larger root per unit of plant weight could be developed (Nielsen, 1979). Liebig (1840) who was one of the first scientist to realize the relationship between the size of the crop and the supply of mineral salts was of the opinion that the supply should correspond to the amount removed by the crop "Law of Restitution".

2.8 Growth and Yield of Pepper as affected by Nutrients and Plant Density Interaction

The yield of pepper is, in addition to other factors, related to the fertility status of the soil and the number of plants per unit area. Increase in plant density is generally

accompanied by an increase in total yield per area up to a certain level. However, increasing plant population generally increases inter - plant competition thereby necessitating the application of higher levels of nutrients to sustain optimum yields. Research reports have indicated that soils which have high native fertility or those that are adequately fertilized are capable of sustaining high population densities. Whereas, soils with low fertility could only support low population density indicating the existence of an interaction between soil fertility status and plant density.

Ramachandran and Subhail (1981) obtained the highest yield at the highest level of 120 kg N/ha and density of 166,667 plants/ha. Manchanda and Bhopal (1987) also reported maximum yield at a combination of 160 kg N/ha and the density of 111,111 plants per hectare. The highest yield of quality seeds has also been reported at a combination of 200 kg N/ha, 49.16 kg P/ha and 37,037 plants/ha (Dharmatti and Kulkarni, 1988). However, Rastogi et al (1980), Isma (1989) Aliyu and Yusuf (1991), Aliyu et al (1994), could not detect any significant interaction between the nutrients and the various plant densities tested on any of the parameters measured.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

Field experiments were conducted on the research farm of the Institute for Agricultural Research, Samaru, Nigeria during the rainy seasons of 1991, 1992 and 1993. Samaru is located in the Northern Guinea Savanna Zone ($11^0 11'N$, $07^0 38'E$ and 686m above sea level) (Keay, 1959). Annual rainfall ranges from 800 - 1300 mm with a long term average (1938 - 1993) of 1054.8 mm and lasts between late April/early May to September/October. Mean maximum and minimum temperatures during the rainy seasons range from 28 - 35^0c and 18 - 22^0c respectively. Meteorological observations at Samaru during the period of the trial are shown in Appendices 1 to 3.

The soil of the area is a loam broadly described as well drained often leached (D'Hoore, 1964; Klinkenberg and Higgins, 1968) ferruginous tropical soil (Tomlinson, 1960: Higgins et al., 1965). It is characterized by low PH, organic matter, and available phosphorus and nitrogen. Physico-chemical properties of the soil at the sites of the trial is presented in Appendix 4.

3.2 Crop Rotation

During the previous seasons, maize, cotton and groundnut were grown on the farms in 1991, 1992 and 1993 respectively.

3.3 Crop Variety

L 5962 - 2 was the material used for this study. The variety is an improved local selection that is cherished both for salad and puree because of the desirable colour of the fruits. It is superior to local cultivars in yield although most exotic varieties yield slightly higher fruits. Average fruit length and diameter were 70 and 40 cm respectively. The fruit colour is green in the immature stage turning bright red on ripening. Single flowers are borne in the axils.

3.4 Experimental Details

The treatments consisted of five nitrogen levels (0, 80, 160, 240 and 320 kg N/ha), three phosphorus levels (0, 22 and 44 kg P/ha) and three plant densities (20,000, 40,000 and 60,000 plants/ha). Calcium ammonium nitrate (26% N) was used as the source of nitrogen. It was applied as a top dressing in three split doses, 25% at two weeks after transplanting (WAT), 50% at six WAT and the remaining 25% at eight WAT. Single superphosphate (18% P_2O_5) was the source for phosphorus and it was applied during land preparation before transplanting of seedlings.

A split-plot design (Cochran and Cox, 1964) was used. Factorial combinations of N and P levels were assigned to the main plot while plant density was allocated to the sub plot. Treatments were replicated three times. A gross plot size of 16.2 m^2 was used in line with the suggestions of Singh (1989), Ramachander and Prabhaker (1989). The gross plot consisted of

six ridges 3.6m long while the inner four ridges were considered as the net plot.

3.5 Cultural Practices

3.5.1 Nursery management

Seeds from previous season's harvest (90.2% germination) were sown on finely tilled beds, mulched with dry grass and watered. The mulch was removed after germination of seeds and the beds were regularly watered and kept free of weeds till the time of transplanting.

3.5.2 Land preparation

The experimental site was ploughed once and harrowed twice at the onset of each rainy season, ridges were then made 75 cm apart and the area marked out into main and sub plots.

3.5.3 Transplanting

Seven week-old seedlings were transplanted out to the field on 1st July in 1991. In 1992 and 1993 five week-old seedlings were transplanted out on 2nd July and 23rd June respectively. Transplanting was done early in the mornings and late evenings to minimize transplanting shock. Uniformly sized seedlings were transplanted to each plot and spaced according to the plant density treatment. Gap filling was done to replace missing stands a week later in each year.

3.5.4 Pests and disease control

In 1991, dimethoate was sprayed at the rate of 1.2l/ha to control aphids. Benomyl and Dithane M 45 were also sprayed at the rate of 1.0 kg/ha each in 1991 and 1992 to control

Anthrachnose and some leaf spot diseases.

Hoe weeding was done as and when necessary to check weed growth in all the years. In 1992, glyphosate at the rate of 4.0l/ha was sprayed two weeks before land preparation to control stoloniferous and rhizomatous noxious weeds.

3.5.5 Harvesting

Fresh fruits were harvested as they ripen from the net plot. Harvesting was done manually.

3.6. Meteorological Data

Data an amount and distribution of rainfall, maximum and minimum temperatures, sunshine hours and relative humidity at Samaru during the period of the experiments were obtained from the meteorological Unit, I. A. R., Samaru.

3.7 Crop Data

The response of the crop to the treatments was evaluated by measuring growth, yield and yield components and also by analysing the plant tissue chemically.

For the assessment of growth parameters random sample of ten plants were selected from each plot using the partial replacement procedure of Gomez and Gomez (1984). Measurements of growth characters were then done on these plants In situ at intervals of two weeks beginning from four weeks after transplanting.

3.7.1 Plant height

The height of randomly selected plants was measured with a meter rule from ground level to the tip of the terminal bud.

3.7.2 Number of branches

This was determined by counting the total number of primary and secondary branches on each plant.

3.7.3 Number of leaves

This was accomplished by counting the total fully expanded leaves on each plant.

3.7.4 Dry aerial phytomass (Dry matter partitioning)

Dry matter accumulation was also determined at different stages of plant growth. In accordance with the recommendations of Hughes and Freeman (1967), Radford (1967), three plants were cut from their bases at each sampling period and separated into leaves, stems and other plant parts (flowers, buds, fruits). The plant parts were then oven dried at 70^0C to a constant weight. The data was subsequently used for growth analyses.

3.7.5 Leaf area

The dry weight disc method of Rhoads and Blood Worth (1964) was used to compute leaf area per plant viz:

$$\text{Leaf area} = \frac{\text{weight of leaves}}{\text{weight of leaf discs}} \times \text{area of leaf discs}$$

3.7.6 Leaf area index

Leaf area Index, the assimilatory surface per unit area was calculated using the following formula given by Watson (1947, 1952).

$$\text{Leaf Area Index (LAI)} = \frac{\text{Total leaf area per plant}}{\text{Area of ground per plant}}$$

3.7.7 Leaf area ratio

This is the ratio of the assimilatory material per unit of plant material present. It was calculated using the formula given by Evans (1972).

$$\text{Leaf area ratio (LAR)} = \frac{A_2 - A^1}{W_2 - W_1} \times \frac{(\log_e W_2 - \log_e W_1}{(\log_e A_2 - \log_e A_1)}$$

W_2 and W_1 represent total dry weights at time t_2 and t_1 respectively when corresponding leaf area was A_2 and A_1

Loge = 2.718

3.7.8 Relative growth rate

The relative growth rate (RGR) is the cumulative dry matter increment per unit of time. It was computed as described by Blackman (1919) and Briggs et al (1920) as follows:

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

where

W_1 and W_2 refers to the total dry matter of plant at times t_1 and t_2 respectively.

3.7.9 Net assimilation rate

This represents the photosynthetic efficiency of assimilatory surfaces. It was computed with the following formula suggested by Gregory (1926), Watson (1958)

$$NAR = \frac{(W_2 - W_1)(\log_e L_2 - \log_e L_1)}{(t_2 - t_1)(L_2 - L_1)}$$

where W_2 and W_1 refers to total dry matter of plant at times t_2 and t_1 when corresponding leaf area was L_2 and L_1 respectively.

3.7.10 Nutrient composition and uptake

Dried plant material were chemically analysed at eight, twelve and fourteen weeks after transplanting to determine the content of nitrogen, phosphorous, potassium, magnesium and calcium. Concentration of nutrients were expressed on the basis of percentage dry plant material. Nutrient uptake was calculated using the respective plant dry weight.

3.7.11 Number of days to 50% flowering

The number of days it took 50% of plants in each plot to flower was counted and recorded.

3.7.12 Number of days to ripeness/maturity

The number of days it took plants to ripen in each plot was also recorded.

3.7.13 Fruit length

Thirty fruits from different plants over several harvests randomly were taken from each plot. The distance between the base to the distal end was then measured with a metre rule.

3.7.14 Fruit diameter

Using a vernier calliper, the diameter towards the based end of thirty randomly selected fruits was measured.

3.7.15 Fresh fruit weight(yield)/plant

Freshly harvested fruits were weighed and the total weight from each plant pooled at the end of harvest.

3.7.16 Fruit dry weight (yield)/plant

Harvested fruits were oven dried to constant weight at 70^0c and the weight recorded.

3.7.17 Number of fruits/plant

The total number of fruits produced by each plant was counted and recorded.

3.7.18 Fresh fruit yield (tons/ha)

The total weight of freshly harvested fruits from the net plot was converted into tons per hectare.

3.7.19 Dry fruit yield (tons/ha)

The total weight of dry fruits harvested from the net plot was converted into tons/hectare.

3.7.20 Number of seeds per fruit

Number of seeds produced by each selected fruit was counted and recorded.

3.7.21 Number of seeds per plant

The total number of seeds produced by each selected plant was pooled at the end of harvest.

3.7.22 Seed yield per plant

The seeds produced per plant were air-dried and weighed.

3.7.23 Seed yield per hectare

The seed yield obtained from the net plot was converted into a hectare basis.

3.8 Analytical Procedures

3.8.1 Soil analysis

Soil samples were collected from a depth of 0 - 30 cm at random each year from the experimental site after land preparation before transplanting. The samples were allowed to dry bulked and analysed for physical and chemical properties.

The soil particle size was analyzed by the hydrometer method (Bouyoucos, 1951) and the textural class determined by using the soil textural triangle (USDA, 1960). Soil PH was determined using the PH meter (Black, 1965). Organic carbon was measured by wet oxidation with dichromate as suggested by Wolf (1982). Total nitrogen was determined by the macro-kjeldahl procedure (Bremner, 1965) using mercuric sulphate and selenium dioxide as catalysts. Available phosphorus was measured in accordance with Bray I sulphuric acid reduction method as described by Trough (1930). Cation exchange capacity and exchangeable bases were estimated using the acetic acid method (A.O.A.C 1975). Sodium and potassium contents were determined with an EEL flame photometer, while calcium and magnesium were determined by atomic absorption spectrophotometry using Perking Elmer model 290B. Exchangeable acidity (H+Al) was assessed by leaching with potassium chloride (Mehlich, 1984).

3.8.2 Plant tissue analysis

Dried sample were ground with a Wiley mill and passed through 0.5mm sieve.

Total nitrogen in plant tissue was also determined by the macro-kjeldahl procedure (IITA, 1975). The procedure involved digesting 0.5gm plant sample with concentrated sulpuric acid using 5g Kjeldahl catalyst mixture. 10ml aliquot of the digest was taken to which 10ml of 10 N sodium hydroxide was added. This was then distilled into boric acid indicator up

to the 150ml mark. The distillate was then titrated against 0.05N sulphuric acid to a pink end point. Percent nitrogen in the sample was calculated as follows:

$$N(\%) = \frac{0.014 \times \text{Titrex vol. of Digest} \times \text{Normality of acid} \times 100}{\text{weight of sample} \times \text{vol. of aliquot used.}}$$

Plant contents of phosphorous, potassium, magnesium and calcium were determined by wet digesting samples with a ternary acid mixture of nitric, sulpuric and perchloric acids (Mehlich, 1978, 1984)). This involved digesting 0.2g sample with the ternary acid mixture. Phosphorous concentration was determined by the vanado-molybdate yellow colour of Bray and Kurtz (1943), Jackson (1958) and modified by Murphy and Riley (1962). To determine the concentration, of potassium, calcium and magnesium, digested sample were taken and diluted. Potassium was determined by flame photometry and calcium and magnesium by atomic absorption spectrophotometry using Perking Elmer model 290B.

3.9 Statistical Analysis

The data collected were subjected to analysis of variance using the 'F' test to look for significance in the effects of the treatments as described by Snedecor and Cochran (1967). Multiple comparison of treatment means were done using the Duncan's Multiple Range Test (Duncan, 1955; 1965; Carmer and Swanson, 1973). Main effects and interactions were determined for all characters in accordance with Gomez and Gomez (1984).

The magnitude and type of relationship between the characters were assessed through simple correlation analysis (Panse and Sukhatme, 1957; Little and Hills, 1978). The direct and indirect contributions of the characters to fruit yield were partitioned using the method of Dewey and Lu (1959), Wright (1960); Singh and Choudhary (1979). The polynomial response of fruit and seed yield to the factors tested; and N and P concentrations to N and P levels were determined through regression analysis as suggested by Steel and Torrie (1984).

3.10 Economic Analysis

Using the data on costs and returns from pepper production during the period of study, net returns and returns per Naira invested on fertilizer were calculated for various N and p level combination.

3.11 Optimum Levels of Nutrients

Using the formula of Garg and Bansal (1972) and Reddy et al . (1975), the optimum levels of N and P were calculated viz:

$$X_{0p} = \frac{b - q/p}{2c}$$

where X_{0p} = optimum level of N or P

b and c = regression constants

q = price per unit of N or P

p = price per unit of fruit or seed.

CHAPTER FOUR

4.0 RESULTS

4.1 Influence of Nitrogen and Phosphorus Levels and Plant Density on the Growth of Pepper

4.1.1 Plant height

Application of nitrogen fertilizer significantly increased the height of pepper plants compared with the control from six weeks after transplanting (WAT) up to 10 WAT in the three years of study (Fig.1A). At 4 WAT only 240 and 320 kg N/ha produced significantly taller plants than the control in 1993. In previous years, there was no significant difference between the various nitrogen levels. The difference between 0 and 80 kg N/ha at 6 WAT and that between 80 and 160 kg N/ha at 8 and 10 WAT was also not significant in 1991. Plant height was not significantly increased beyond 160 kg N/ha in 1992 from 6 WAT to 10 WAT, whilst it increased significantly up to 240 kg N/ha in 1993 within the same period.

Phosphorus fertilizer application did not result in any significant increase in plant height in 1991 (Fig 1B) in all the weeks studied. At 6, 8 and 10 WAT the two phosporus levels (22 and 44 kg p/ha) produced significantly taller plants than the co0ntrol in 1992 and 1993. At 4 WAT there was no significant difference in plant height between the two

levels and the control in 1992.

Planting at 20,000 and 40,000 plants/ha resulted in significantly taller plants at 6, 8 and 10 WAT in 1993 (Fig 1C). At 4 WAT in 1993 and all the weeks in 1991 and 1992, there was no significant difference between the three densities.

Plant height at 8 WAT was significantly influenced by an interaction between nitrogen and plant density in 1992 (Table 1.). At 0 and on applying 240 and 320 kg N/ha, the three planting densities were comparable in the height of plants at such desities, whilst application of 80 and 160 kg N/ha resulted in significantly shorter plants when grown at 60,000 plants/ha. Each additional increment in nitrogen level resulted in significantly increased plant height at the higher densities of 40,000 and 60,000 plants/ha. At 20,000 plants/ha 160 and 240 kg N/ha were at par.

Plant height was also significantly affected by an interaction between nitrogen and phosphorus level at 10 WAT in 1992 (Table 2). At 0 and 320 kg N/ha, there was no significant difference between the phosphorus levels. At other levels of N, application of 44 kg p/ha significantly

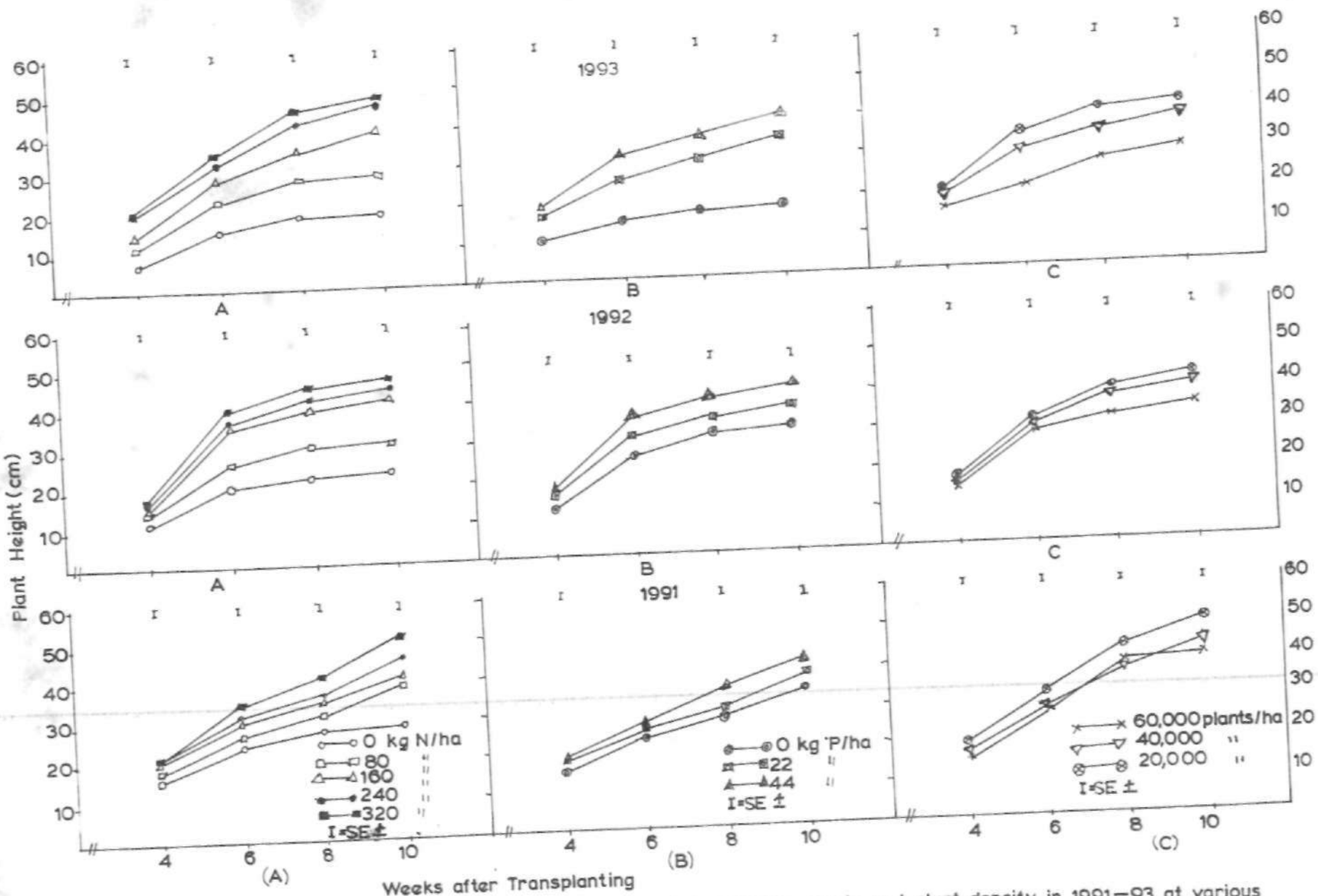


Fig. 1 Height of Pepper plant as influenced by nitrogen and phosphorus levels and plant density in 1991–93 at various sampling periods.

increased plant height compared with o kg p/ha, other although it was comparable with 22kg p/ha. When 44 kg p/ha was applied each additional nitrogen level significantly increased plant height.

4.1.2 Number of branches/plant

Number of branches/plant was significantly increased with increase in nitrogen levels up to 240 kg N/ha in all the three years at 8 and 10 WAT (Fig 2A). In 1991 the four nitrogen rates were significantly similar and higher than the control at 4 WAT whereas at 6 WAT, 80 and 160 kg N/ha resulted in more branches than 240 kg N/ha. Application of 160 kg N/ha resulted in significantly more branches compared with other levels at 4 WAT in 1992. In subsequent weeks production of branches was not significantly increased beyond 160 kg N/ha. Similarly at 4 and 6 WAT number of branches was not significantly increased beyond 160 kg N/ha in 1993.

Application of 44 kg P/ha resulted in formation of greater number of branches compared with 0 kg P/ha as from 6 WAT (Fig 2B) in each year of study. The branches produced on application of 22 kg P/ha were not statistically different from those obtained at 0 kg P/ha at 4 and 6 WAT in each year. Similarly, there was no significant difference in the number of branches produced on application of 44 and 22 kg P/ha at 4 and 6 WAT in 1991 and 1993 and also at 4, 8 and 10 WAT in 1993.

Table 1. Interaction between Nitrogen and Plant density on plant height (cm) at 8 WAT in 1992

Treatment	Plant height(cm)		
(Plants/ha)	20,000	40,000	60,000
Nitrogen (Kg N/ha)			
0	16.67 g	16.49 g	16.23 g
80	30.84 e	29.74 e	27.03 f
160	37.97 bc	36.61 c	33.54 d
240	38.56 bc	39.05 b	37.70 bc
320	44.38 a	44.07 a	43.64 a
SE± 0.752			

Means followed by same alphabet(s) are similar statistically using DMRT at 5 %.

Table 2. Plant height (cm) at 10 WAT as affected by Nitrogen and Phosphorus interaction in 1992.

Treatment	Plant height (cm)		
Phosphorus (Kg P/ha)			
Nitrogen (Kg N/ha)	0	22	44
0	17.67 h	18.54 h	19.95 h
80	24.43 g	30.94 f	34.01 ef
160	37.14 de	38.45 cd	41.66 c
240	38.09 cd	38.51 cd	43.19 b
320	46.24 ab	46.39 ab	47.05 a
SE± 1.199			

Means followed by same alphabet(s) are statistically similar using DMRT at 5%.

Number of branches was not significantly affected by the three densities in 1991 in all the periods and at 4 and 6 WAT in 1992 and 1993 (Fig.2C). At 10 WAT in 1992 and also at 8 and 10 WAT in 1993, more branches were produced as a result of planting at 20,000 plants/ha compared with 60,000 plants/ha. The difference between 40,000 plants/ha and the other two densities was not significant in 1992.

There was no significant interaction between any of the factors on number of branches in the three years of study.

4.1.3 Number of leaves/plant.

Nitrogen fertilizer application significantly increased number of leaves produced by pepper plant compared with the control at all periods in all the years (Fig.3A). At 8 WAT each additional nitrogen level resulted in significant increase in number of leaves produced in all the years. At 10 WAT leaf production was not significantly increased beyond 240 kg N/ha. 160 and 80 kg N/ha resulted in more leaves compared with other levels at 4 WAT in 1992. In 1991 and 1993 at 4 WAT there was no significant difference between the various nitrogen levels. At 6 WAT, more leaves were produced on application of 240 and 320 kg N/ha compared with lower rates in the three years. The two levels were however, similar statistically.

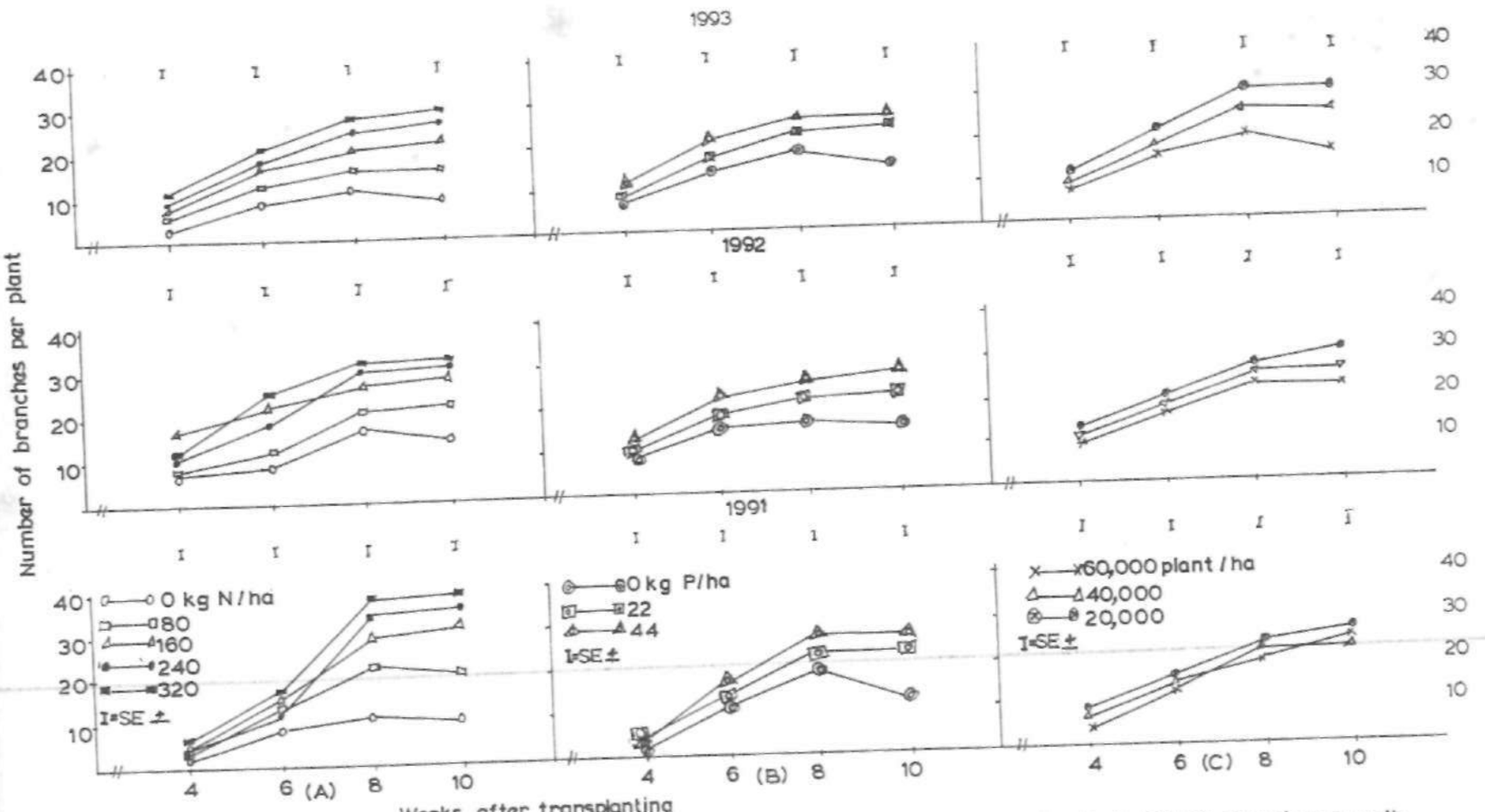


Fig. 2 Number of branches as affected by nitrogen and phosphorus levels and plant density in 1991-93 at various growth stages.

The number of leaves per plant was significantly increased with each phosphorus level at 10 WAT in 1991 and 1993 (Fig. 3B). In 1992, the application of 22 was comparable with 44 kg P/ha, and the two levels resulted in significantly more leaves compared with 0 kg P/ha at 10 WAT and also at 6 and 8 in the three years. At 4 WAT the difference in leaves produced by the three levels was not significant.

Significantly more leaves were produced on planting at 20,000 and 40,000 plants/ha compared with 60,000 plants/ha at 10 WAT in all the years, and also at 6 and 8 WAt in 1992 and 1993. The difference between 40,000 and 60,000 plants/ha was only significant at 6 WAT in 1993. Similarly leaf production was not significantly affected by the density treatments at 4 WAT in all the years. None of the 1st order and 2nd order interaction was significant on leaf production.

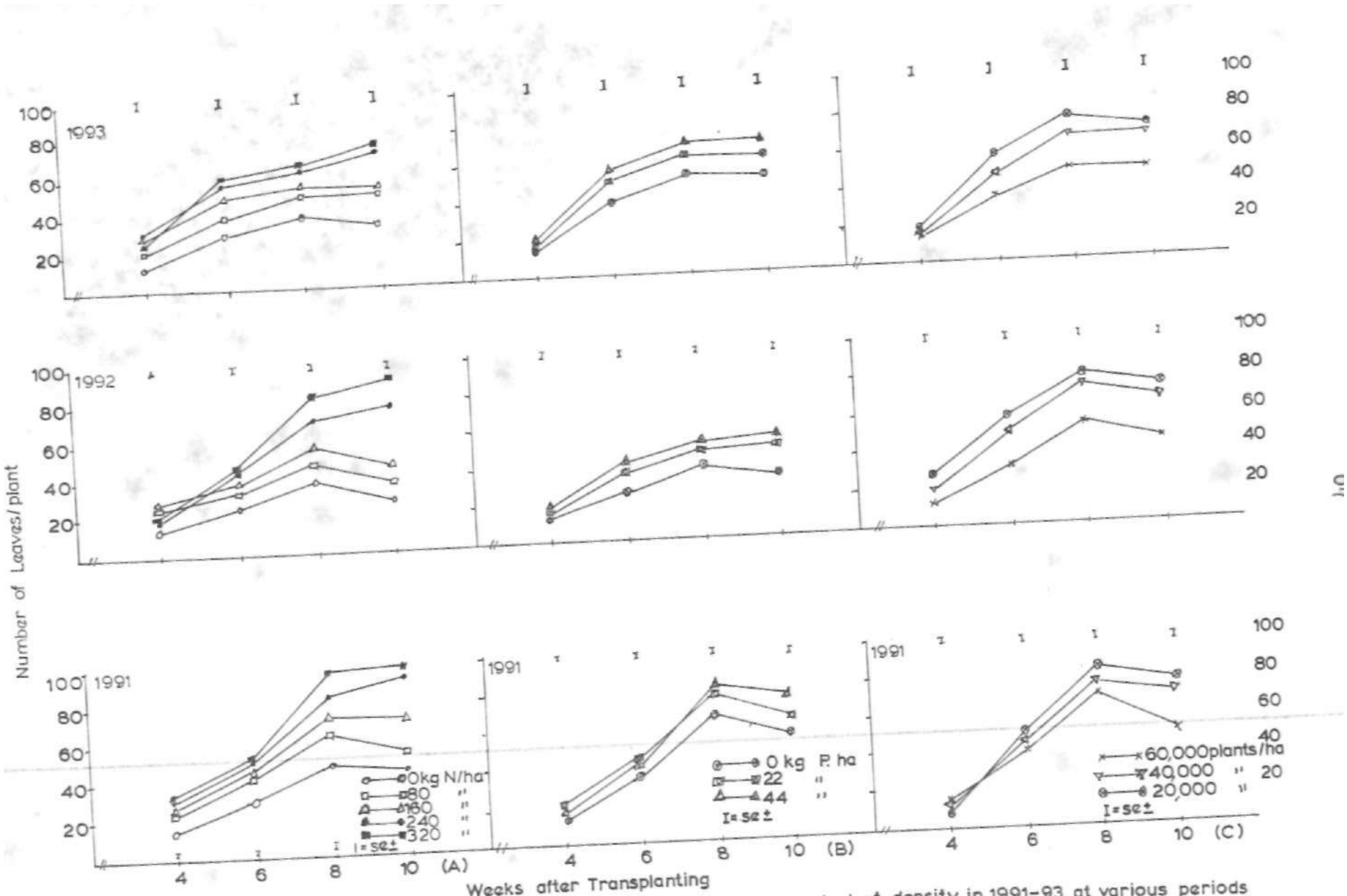


Fig. 3 Number of Leaves as affected by nitrogen and phosphorus levels and plant density in 1991-93 at various periods

4.1.4 Leaf dry weight

Leaf dry weight increased from transplanting peaked at 8 WAT and subsequently declined at 10 WAT (Fig.4,5 and 6). Significant increases were obtained in leaf dry weight with each additional nitrogen level up to 320 kg N/ha at 8 and 10 WAT in all the years (Fig.4). The difference between 80, 160 and 240 kg N/ha was not significant at 4 and 6 WAT in 1991. Leaf dry weight was however significantly heavier on application of 240 kg N/ha compared with lower N level at 4 and 6 WAt in 1992 and 1993.

Phosphorus application significantly increased leaf dry weight compared with the control at all stages of growth and in all the years (Fig.5). The difference in leaf dry weight between 22 and 44 kg p/ha was however not significant.

Leaf dry weight was significantly increased when 20,000 plants/ha and 40,000 plants/ha were used compared with 60,000 plants/ha at all the periods of sampling and in all the years (Fig.6). However, 20,000 plants/ha was significantly different from 40,000 plants/ha only at 8 and 10 WAT in 1991.

At 8 WAt in 1991 leaf dry weight was significantly affected by a first order interaction between nitrogen levels and plant density (Table 3). When no nitrogen was added and when only 80 kg N/ha was supplied, the difference between 40,000 and 60,000 plants was not significant. At higher levels however each density level resulted in a different leaf dry weight. At all densities each increase in N level

increased leaf dry weight significantly.

4.1.5 Stem dry weight

Heaviest dry stems were obtained on application of the highest level of 320 kg N/ha from 4 WAT to 10 WAT in the three years (Fig.4). The difference compared with other N levels was also significant except at 6 WAT in 1991 when 320 kg N/ha compared with 240 kg N/ha. Each level also resulted in significantly heavier dry stems compared with a previous lower level of application.

Stem dry weight was significantly increased on application of 22 kg P/ha throughout the period of study (Fig.5). Weights were however comparable with those produced on increasing phosphorus level to 44 kg P/ha.

Transplanting at 20,000 plants/ha resulted in significantly heavier dry stems compared with 60,000 plants/ha in the three years of study and at all sampling periods (Fig.6). 40,000 plants/ha significantly compared with 20,000 plants/ha at 4 and 6 WAT in 1991 - 1993 and also at 8 WAT in 1992 in stem dry weight. Differences in stem dry weight between 40,000 plants/ha and 60,000 plants/ha were also significant in the three years and at all sampling periods.

A significant interaction between nitrogen levels and plant density was recorded on stem dry weight at 4 WAT in 1991 (Table 4). Stem dry weight significantly decreased from 20,000 plants/ha down to 60,000 plants/ha when 240 and 320 kg N/ha was applied. At other levels of N the difference in stem

dry weight between the three plant densities was not significant. Up to 160 kg N/ha stem dry weight at different plant densities was not significant; however, 320 kg N/ha produced higher stem dry weight compared with 240 kg N/ha.

Table 5 shows the influence of NxP interaction on stem dry weight at 6 WAT in 1991. Heaviest dry stems were produced when a combination of 320 kg N/ha and 22 kg P/ha was used whilst the lowest value for stem dry weight was recorded when neither N or P fertilizer was applied.

Phosphorus levels also interacted with plant density at 4 WAT in 1991 (Table 6). At the 0 kg N/ha there was no significant difference in stem dry weight between the three densities. However on adding 22 kg P/ha, stem dry weight decreased significantly when a density of 60,000 plants/ha was used compared with lower densities which were at par. On increasing the P level to 44kg P/ha, stem dry weight also decreased at the 40,000 plants/ha compared with 20,000 plants/ ha. The stem dry weight was significantly affected only at 20,000 plants/ha when the two P rates significantly out yielded the control.

4.1.6 Dry weights of bud, flower and fruit

Irrespective of treatment, the dry weights of bud, flower and fruits were minimal up to 8 WAT (Fig.4, 5, and 6) and there was no significant difference between the various treatments. However, after 8 WAT, the dry weights of bud flower and fruit steadily increased up to the last sampling

period (10 WAT) when it comprised of a large proportion of the total dry matter partitioned.

At 10 WAT dry weights of bud flower and fruit progressively increased with each additional nitrogen level up to 320 kg N/ha (Fig.4). The difference between the various levels was significant up to 240 N/ha only.

Application of phosphorus did not significantly increase the dry weight of bud, flower and fruit in the years of study.

The three plant densities were also significantly comparable in the dry weights of bud, flower and fruit produced by their plants in the three years.

There was no significant interaction between any of the factors on dry weights of bud flower and fruit throughout the duration of experiment.

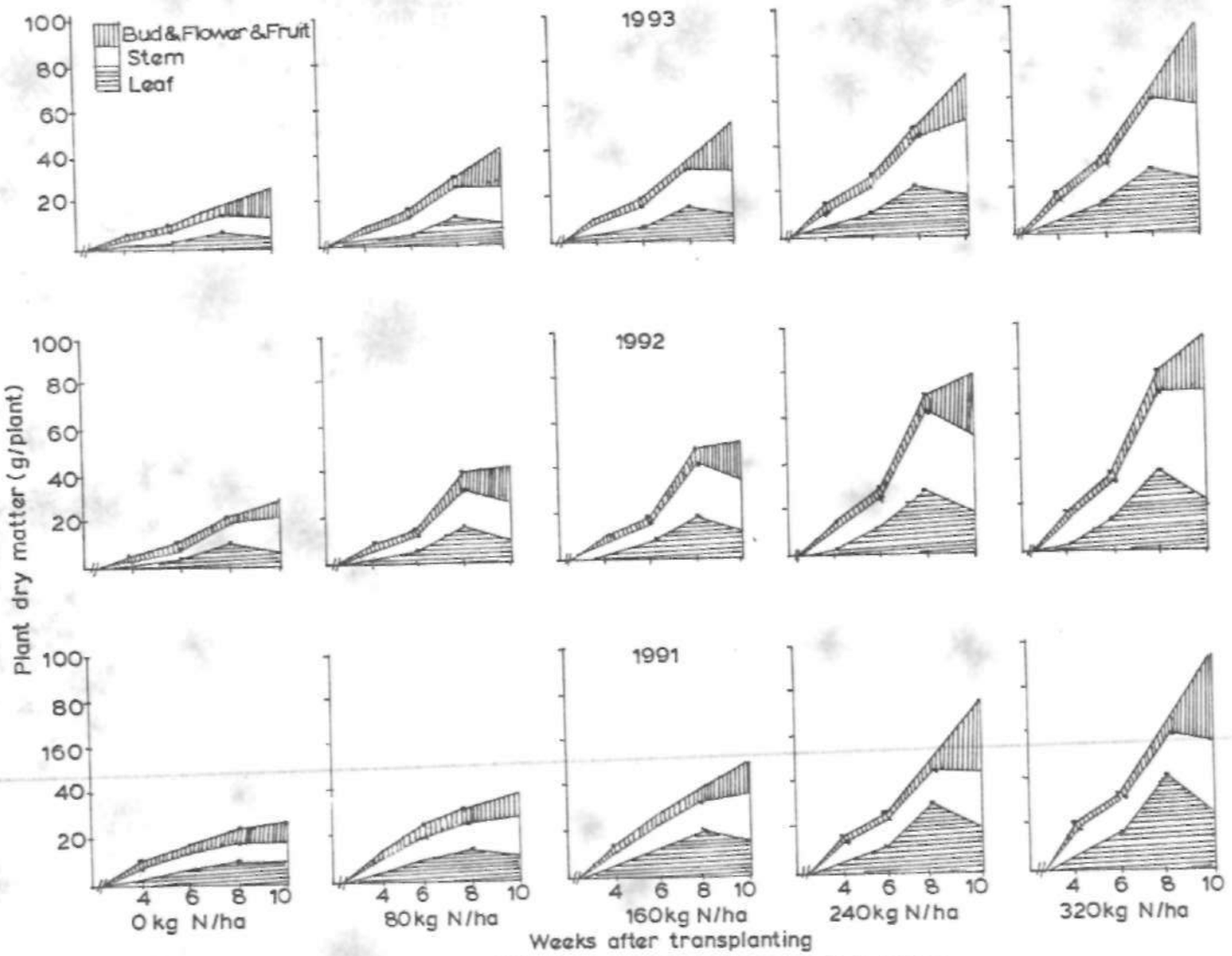


Fig 4 Cumulative dry matter partitioning as affected by nitrogen levels

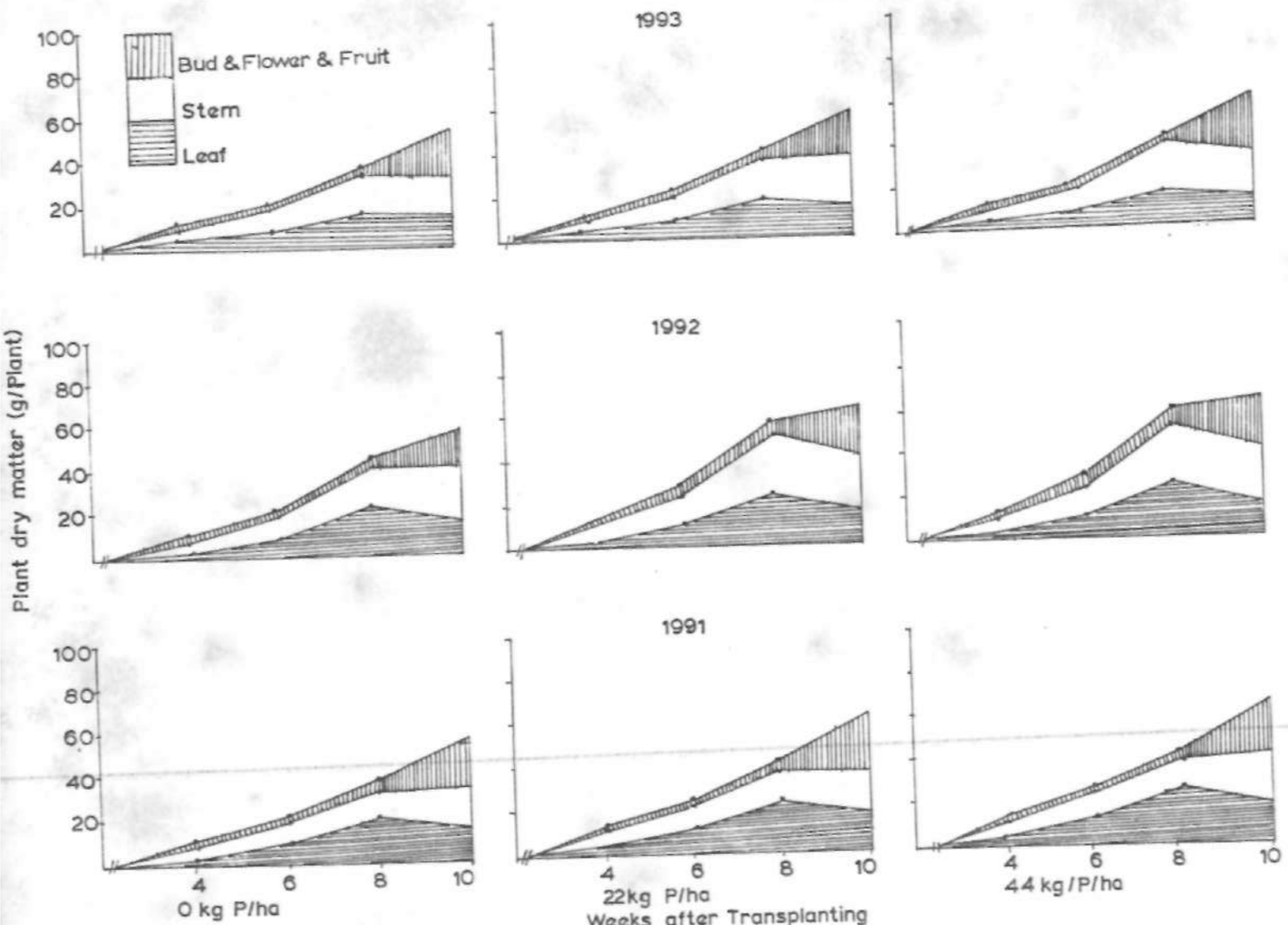


Fig. 5 Cumulative dry matter partitioning as affected by phosphorus levels

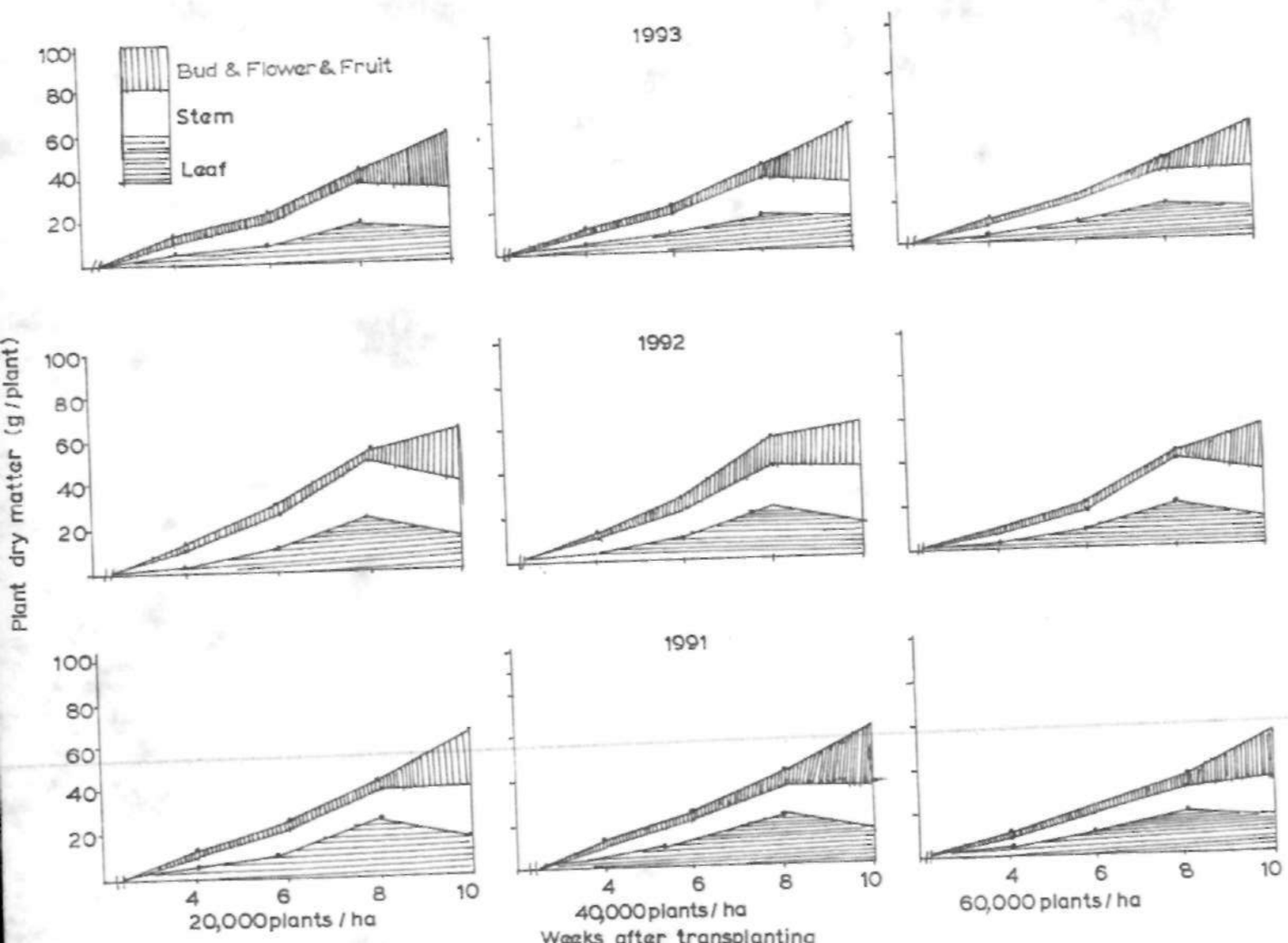


Fig. 6 Cumulative dry matter partitioning as influenced by plant density

Table 3. Interaction between nitrogen and plant density on leaf dry weight (g) at 8 WAT in 1991.

Treatment	Leaf dry weight (g)		
Plant density (Plant/ha)			
	20,000	40,000	60,000
Nitrogen (Kg N/ha)			
0	11.96 i	10.11 j	10.01 j
80	15.94 h	12.71 i	12.08 i
160	22.74 f	19.91 g	15.29 h
240	33.89 c	29.70 d	25.12 e
320	44.84 a	41.21 b	33.58 c
SE± 0.615			

Means followed by similar alphabet(s) are significantly same using DMRT at 5%.

Table 4. Stem dry weight (g) at 4 WAT as influenced by nitrogen x plant density interaction in 1991.

Treatment	Stem dry weight (g)		
Plant density (Plants/ha)			
	20,000	40,000	60,000
Nitrogen (kg N/ha)			
0	5.41 fgh	4.92 gh	4.06 h
80	6.26 efg	5.85 fg	5.80 fg
160	6.95 ef	6.28 efg	5.85 fg
240	11.95 c	9.44 d	7.42 e
320	15.54 a	13.87 b	10.42 cd
SE± 0.615			

Means followed by same alphabet(s) are significantly similar using DMRT at 5%.

Table 5. Stem dry weight (g) at 6 WAT as influenced by nitrogen x phosphorus interaction in 1991.

Treatment	Stem dry weight (g)		
Phosphorus (kg P/ha)	0	22	44
Nitrogen (Kg N/ha)			
0	6.51 e	9.12 cd	8.20de
80	9.58 cd	9.45 cd	10.94 c
160	9.19 cd	10.59 c	14.27 b
240	14.64 ab	14.98 ab	15.85 ab
320	15.54 ab	16.51 a	16.21 a
SE± 0.639			

Means followed by same alphabet(s) are similar statistically using DMRT at 5%.

Table 6. Stem dry weight (g) at 4 WAT as affected by phosphorus x plant density interaction in 1991.

Treatment	Stem dry weight (g)		
Plant density (Plants/ha)	20,000	40,000	60,000
Phosphorus (Kg P/ha)			
0	7.55 cd	7.31 cde	6.78 de
22	9.69 ab	8.42 bc	6.05 e
44	10.43 a	8.48 bc	7.19 cde
SE± 0.477			

Means followed by same letter(s) are significantly similar using DMRT at 5%.

4.1.7 Total dry weight/plant

Unlike some of the partitioned dry weights, total dry weight did not decline after 8 WAT irrespective of treatment and year. It increased up to 10 WAT and significant differences were observed between the treatments at each period of sampling (Tables 7, 9 and 10).

Total dry weight significantly increased with each increment in nitrogen level up to 320 kg N/ha in the years of study and at all periods of sampling (Table 7, 9 and 19).

Application of 22 kg P/ha significantly increased total dry weight over the control in all the years and at all periods of study. (Tables 7, 9 and 10). Increasing phosphorus level to 44 kg P/ha produced significant increase in total dry weight over 22 kg P/ha at 6 WAt in 1991 and, at 4, 8 and 10 WAT in 1993. 44 kg P/ha consistently produced significantly heavier total dry weights compared with 0 kg P/ha throughout the period of study.

Total dry weight significantly decreased with each increase in plant density from 20,000 plants/ha up to 60,000 plants/ha throughout the period of study (Tables 7, 9 and 10).

Table 7. Effect of nitrogen and phosphorus levels and plant density on total dry weight(g) at different sampling periods.

Treatment	Dry Weight(g/Plant)			
	4 WAT	6 WAT	8 WAT	10 WAT
Nitrogen(Kg N/ha)				
0	8.04 e	15.22 e	25.01 e	29.80 e
80	9.65 d	20.71 d	27.31 d	39.87 d
160	10.89 c	23.62 c	34.36 c	51.60 c
240	14.11 b	27.69 b	50.79 b	75.81 b
320	19.10 a	31.78 a	63.20 a	94.90 a
SE±	0.384	0.397	1.649	2.592
Phosphorus (kg P/ha)				
0	11.22 b	22.11 c	32.59 b	55.50 b
22	12.52 a	24.21 b	41.98 a	61.50 a
44	13.33 a	25.60 a	40.83 a	62.70 a
SE±	0.297	0.307	1.277	1.421
Plant density (plants/ha)				
20,000	14.00 a	25.60 a	43.09 a	64.50 a
40,000	12.44 b	24.21 b	40.93 b	61.50 b
60,000	10.64 c	21.60 c	36.39 c	54.00 c
SE±	0.281	0.300	0.939	1.409
Interactions				
N X P	NS	NS	NS	NS
N X D	XX	NS	NS	NS
P X D	NS	NS	NS	NS
NXPXD	NS	NS	NS	NS

Means followed by different alphabets within a column of any set of treatment are significantly different at 5% level of significance using DMRT.
NS = Interaction not significant at 5% significance level
XX = Highly significant interaction at 1% signifiance level

A highly significant interaction was observed between N levels and plant density on total dry weight at 4 WAT in 1991 (Table 8). At 0 kg N/ha total dry weight was not affected by differences in plant density. However at 240 and 320 kg N/ha increasing population density significantly decreased total dry weight. When the different plant densities are considered, each increase in N from 160 to 320 significantly increased the total dry weight.

Table 8. Interaction between nitrogen and plant density on total dry weight at 4 WAT in 1991.

Treatment	Total dry weight (g)		
	Plant Density (Plants/ha)		
	20,000	40,000	60,000
Nitrogen(Kg N/ha)			
0	8.56 hij	7.89 j	7.70j
80	10.43 fg	10.29 fgh	8.24 ij
160	11.99 f	10.78 fg	9.90 hi
240	17.09 c	13.85 e	11.40 fg
320	21.95 a	19.42 b	15.90 d
SE± 0.621			

Means followed by different alphabet(s) are significantly different at 1% level using DMRT.

Table 9. Effect of nitrogen and phosphorus levels and plant density on total dry weight(g) at different sampling periods, in 1992.

Treatment	Dry weight (g/plant)			
	4 WAT	6 WAT	8 WAT	10 WAT
Nitrogen(Kg N/ha)				
0	5.16 e	10.66 e	22.24 e	28.60 e
80	7.42 d	15.33 d	40.67 d	41.60 d
160	9.10 c	19,oo c	49.25 c	50.70 c
240	14.18 d	28.92 b	69.91 b	78.00 b
320	16.78 a	34.71 a	79.33 a	93.60 a
SE±	0.239	0.496	1.025	1.333
Phosphorus (kg p/ha)				
0	10.17 b	21.07 b	43.55 b	57.20 b
22	12.54 a	28.73 a	56.96 a	61.10 a
44	12.88 a	29.00 a	57.52 a	62.40 a
SE±	0.185	0.382	0.789	1.02
Plant density (plants/ha)				
20,000	13.39 a	29.55 a	58.65 a	63.70 a
40,000	12.57 b	28.72 b	56.94 b	59.80 b
60,000	9.62 c	19.75 c	40.80 c	53.30 c
SE±	0.110	0.227	0.469	0.610
Interactions				
N X P	NS	NS	NS	NS
N X D	NS	NS	NS	NS
P X D	NS	NS	NS	NS
NXPXD	NS	NS	NS	NS

Means in a column of any set of treatments followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

Table 10. Effect of nitrogen and phosphorus levels and plant density on total dry weight(g) at different sampling periods, in 1993.

Treatment	Dry weight (g/plant			
	4 WAT	6 WAT	8 WAT	10 WAT
Nitrogen(Kg N/ha)				
0	5.16 e	9.72 e	18.76 e	25.78 e
80	8.35 d	15.71 d	29.92 d	42.96 d
160	9.10 c	18.70 c	35.53 c	51.55 c
240	14.41 b	26.18 b	48.99 b	70.18 b
320	18.40 a	34.41 a	64.35 a	91.65 a
SE±	0.236	0.441	0.825	1.181
Phosphorus (kg P/ha)				
0	10.45 c	19.64 b	36.73 c	52.98 c
22	11.36 b	21.32 a	39.83 b	57.28 b
44	11.93 a	22.31 a	41.72 a	60.14 a
SE±	0.187	0.342	0.640	0.916
Plant density (plants/ha)				
20,000	11.93 a	22.31 a	41.14 a	58.71 a
40,000	11.24 b	21.02 b	39.22 b	55.85 b
60,000	10.58 c	19.82 c	37.40 c	52.58 c
SE±	0.127	0.238	0.445	0.637
Interactions				
N X P	NS	NS	NS	NS
N X D	NS	NS	NS	NS
P X D	NS	NS	NS	NS
NXPXD	NS	NS	NS	NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

4.1.8 Leaf area/plant

With the exception of 160 kg N/ha and 60,000 plants/ha in 1991, leaf area/plant for other treatment increased from transplanting up to 8 WAT after which it declined. For 160 kg N/ha and 60,000 plant/ha leaf area increased up to 10 WAT: (Tables 11, 12 and 13).

In 1991 leaf area was not significantly increased beyond 240 kg N/ha at 6 WAT. At other periods, and in subsequent years, a significant increase was recorded with each increment in nitrogen level up to 320 kg N/ha (Tables 11, 12 and 13).

Phosphorus application significantly increased leaf area compared with the control at all periods and in the three years of study (Tables 11, 12 and 13). The difference between 22kg P/ha and 44 kg P/ha in terms of their influence on leaf area/plant was significant at 6 WAT in 1991, and 1993 and at all periods of sampling in 1992.

The leaf area regressed significantly at every increment of plant density from 20,000 plants/ha to 60,000 plants/ha at all the periods in 1991 (Table 11). The same trend was observed at 4 and 6 WAT in 1992 and 1993 (Tables 12 and 13 respectively). There was no significant difference in leaf area between the various densities at 8 and 10 WAT in 1992. At the same period in 1993, 20,000 plants/ha was significantly superior to 40,000 and 60,000 plants/ha in terms of leaf area. The two higher densities were however similar in their leaf area production.

Table 11. Effect of nitrogen and phosphorus levels and plant density on leaf area/plant (cm^2) at various sampling periods, in 1991.

Treatment	Leaf area (cm^2/plant)			
	4 WAT	6 WAT	8 WAT	10 WAT
Nitrogen(Kg N/ha)				
0	937.75 e	1883.75 d	2736.25 e	2457.00e
80	1443.75 d	2901.25 c	3313.75 d	3355.00d
160	1815.00 c	3685.00 b	4001.25 c	4193.75c
240	2255.00 b	4345.00 a	4592.50 b	4565.00b
320	2392.50 a	4482.50 a	5018.75 a	4950.00a
SE±	39.875	82.500	149.875	126.5000
Phosphorus (kg P/ha)				
0	1622.50 b	3190.00 c	3712.50 b	3685.00 b
22	1801.25 a	3478.75 b	4015.00 a	3973.75 a
44	1870.00 a	3698.75 a	4070.00 a	4056.25 a
SE±	30.250	63.250	115.90	97.624
Plant density (plants/ha)				
20,000	2610.00 a	4972.50 a	5827.50 a	5760.00 a
40,000	1361.25 b	2700.00 b	3183.75 b	3116.25 b
60,000	1117.50 c	2197.50 c	2370.00 c	2385.00c
SE±	28.875	53.625	95.375	82.312
Interactions				
N X P	NS	NS	NS	NS
N X D	NS	NS	NS	NS
P X D	NS	NS	NS	NS
NXPXD	NS	NS	NS	NS

Means in a column of any set of treatments followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

Table 12. Effect of nitrogen and phosphorous levels and plant density on leaf area/plant (cm^2) at various sampling periods, in 1992.

Treatment	Leaf area (cm^2/plant)			
	4 WAT	6 WAT	8 WAT	10 WAT
Nitrogen(Kg N/ha)				
0	426.25 e	797.50 e	1553.75 e	1361.25 e
80	976.00 d	1402.50 d	3355.00 d	2956.25 d
160	1155.00 c	2310.00 c	4138.75 c	3643.75 c
240	1430.00 b	2970.oo b	5060.00 b	4441.25 b
320	1636.25 a	3080.00 a	5692.50 a	5005.00 a
SE±	27.500	41.250	82.500	68.750
Phosphorus (kg P/ha)				
0	1058.75 c	1815.00 c	3355.00 c	2956.25 c
22	1113.75 b	2090.00 b	3932.50 b	3465.00 b
44	1196.25 a	2255.00 a	4235.00 a	3726.25 a
SE±	17.875	33.000	68.750	55.00
Plant density (plants/ha)				
20,000	1530.00 a	2250.00 a	3172.50	2520.00
40,000	922.90 b	1732.50 b	3262.50	2868.75
60,000	712.50 c	1552.50 c	3270.00	2970.00
SE±	20.625	38.500	72.875	169.625
Interactions				
N X P	NS	NS	NS	NS
N X D	NS	NS	NS	NS
P X D	NS	NS	NS	NS
NXPXD	NS	NS	NS	NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

Table 13. Effect of nitrogen and phosphorus levels and plant density on leaf area/plant (cm^2) at various sampling periods, in 1993.

Treatment	Leaf are (cm^2/plant)			
	4 WAT	6 WAT	8 WAT	10 WAT
Nitrogen(Kg N/ha)				
0	440.00 e	811.25 e	1500.00 e	1141.25 e
80	811.25 d	1498.75 d	2777.50 d	2117.50 d
160	1003.75 c	1856.25 c	3437.50 c	2612.50 c
240	1320.00 b	2447.50 b	4523.75 b	3437.50 b
320	1608.75 a	2970.00 a	5486.25 a	4166.25 a
SE±	38.500	71.500	132.00	100.375
Phosphorus (kg P/ha)				
0	976.25 b	1801.25 c	3313.75 b	2516.25 b
22	1058.75 a	1952.50 b	3616.25 a	2750.00 a
44	1113.75 a	2062.50 a	3822.50 a	2901.25 a
SE±	30.250	56.375	104.500	79.750
Plant density (plants/ha)				
20,000	1395.00 a	2362.50 a	3442.50 a	2520.00 a
40,000	832.50 b	1541.25 b	2846.25 b	2160.00 b
60,000	690.00 c	1350.00 c	2812.50 b	2167.50 b
SE±	20.625	38.500	71.750	55.250
Interactions				
N X P	NS	NS	NS	NS
N X D	NS	NS	NS	NS
P X D	NS	NS	NS	NS
NXPXD	NS	NS	NS	NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

4.1.9 Leaf area index

The effect of nitrogen and phosphorus levels and plant density and their interaction on leaf area index at different periods in 1991 - 1993 is shown on Tables 14, 15, 16 and 17.

Generally, leaf area index increased from transplanting peaked at 8 WAT and declined at 10 WAT. However application of 160 kg N/ha and the plant density of 60,000 plants/ha in 1991, exhibited a different trend in that under such treatments, leaf area index (LAI) increased even at 10 WAT.

In 1991 LAI increased with nitrogen application from 0 kg N/ha to 320 kg N/ha at 4 and 10 WAT (Table 14). At 6 and 8 WAT significant increases were obtained up to 240 kg N/ha Except for LAI at 6 WAT in 1992 where 240 kg N/ha and 320 kg N/ha were similar, each additional N level signifiantly increased LAI up to the highest level in 1992 and 93.

Leaf area index was also significantly affected by applied phosphorus in all the years. In 1991 the two rates increased LAI compared with the control throughout the period under test, although there was no significant difference between the two rates except at 6 WAT when 44 kg increased P/ha had an edge in LAI over 22 kg P/ha. In 1992, there was a linear increase with each increment in P. However, in 1993, LAI from plots supplied with 22 kg P/ha were statistically comparable with those without P and those given 44 kg P/ha at 4, 6 and 8 WAT, although the difference between 44 kg P/ha and 0 kg P/ha was significant. At 10 WAT the two rates of applied P were similar and resulted in signifciantly higher LAI

compared with the control.

The three plant densities tested were significantly different in terms of LAI in the three years of study. There was a progressive increase in LAI with increase in plant density from 20,000 plants/ha to 60,000 plants/ha in all the years.

Table 14. Leaf area Index as influenced by nitrogen and phosphorus levels and plant density at different periods in 1991.

Treatment	Leaf area index			
	4 WAT	6 WAT	8 WAT	10 WAT
Nitrogen(Kg N/ha)				
0	0.68 e	1.37 d	1.99 d	1.80 e
80	1.05 d	2.11 c	2.41 c	2.44 d
160	1.32 c	2.68 b	2.91 b	3.05 c
240	1.62 b	3.16 a	3.34 a	3.32 a
320	1.74 a	3.26 a	3.65 a	3.60 a
SE±	0.029	0.060	0.109	0.092
Phosphorus (kg P/ha)				
0	1.18 b	2.32 c	2.70 b	2.68 b
22	1.31 a	2.53 b	2.92 a	2.89 a
44	1.36 a	2.69 a	2.96 a	2.95 a
SE±	0.022	0.046	0.084	0.071
Plant density (plants/ha)				
20,000	1.16 c	2.21 c	2.59 c	2.56 c
40,000	1.21 b	2.40 b	2.83 b	2.77 b
60,000	1.49 a	2.97 a	3.16 a	3.18 a
SE±	0.021	0.039	0.037	0.037
Interactions				
N X P	NS	NS	NS	NS
N X D	NS	NS	NS	X
P X D	NS	NS	NS	NS
NXPXD	NS	NS	NS	NS

Means in a column of any set of treatments followed by different alphabet(s) are significantly different at 5% significance level using DMRT.
X Interaction significant at 5% significance level
NS Interaction not significant even at 5% level significance.

A significant interaction between N levels and plant density was recorded on LAI at 10 WAT in 1991 (Table 15). There was a significant increase in LAI as density was increased at all N levels except in control 160 and 320kg N/ha in which the difference between 20 and 40,000 plants/ha was not significant. When the densities were looked at various N levels, there was an increase in the LAI in all cases except 160 and 240 kg N/ha under 20,000 plants and 240 and 320 kg both in 40 and 60,000 plants. Maximum leaf area index was obtained when a combination of 60,000 plants ha and 320 kg N/ha was used. Minimum leaf area index was recorded when no nitrogen (0 kg N/ha) was used at a density of 20,000 plants/ ha.

Table 15. Interaction between nitrogen and plant density on leaf area index at 10 WAT in 1991.

Treatment	Leaf area index		
	Plant density (Plants/ha)		
	20,000	40,000	60,000
Nitrogen(KgN/ha)			
0	1.58 g	1.75 g	2.07 f
80	2.08 f	2.44 e	2.79 d
160	2.80 d	2.95 d	3.39 bc
240	2.85 d	3.35 c	3.82 a
320	3.51 b	3.46 bc	3.85 a
SE± 0.084			

Means followed by unlike alphabet(s) are significantly different at 5% significance level using DMRT.

Table 16 Leaf area Index as influenced by nitrogen and phosphorus levels and plant density at different periods in 1992.

Treatment	Leaf area index			
	4 WAT	6 WAT	8 WAT	10 WAT
Nitrogen(Kg N/ha)				
0	0.31 e	0.58 d	1.13 e	0.99 e
80	0.71 d	1.02 c	2.44 d	2.15 d
160	0.84 c	1.68 b	3.01 c	2.65 c
240	1.04 b	2.16 a	3.68 b	3.27 b
320	1.19 a	2.24 a	4.14 a	3.64 a
SE±	0.016	0.030	0.056	0.050
Phosphorus (kg P/ha)				
0	0.77 c	1.32 c	2.44 c	2.15 c
22	0.81 b	1.52 b	2.86 b	2.52 b
44	0.87 a	1.64 a	3.08 a	2.71 a
SE±	0.013	0.024	0.045	0.040
Plant density (plants/ha)				
20,000	0.68 c	1.00 c	1.41 c	1.26
40,000	0.82 b	1.54 b	2.90 b	2.55 b
60,000	0.95 a	2.07 a	4.36 a	3.96 a
SE±	0.015	0.028	0.053	0.047
Interactions				
N X P	NS	NS	NS	NS
N X D	NS	NS	NS	NS
P X D	NS	NS	NS	NS
NXPXD	NS	NS	NS	NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

Table 17 Leaf area Index as influenced by nitrogen and phosphorus levels and plant density at different periods in 1993.

Treatment	Leaf area index			
	4 WAT	6 WAT	8 WAT	10 WAT
Nitrogen(Kg N/ha)				
0	0.32 e	0.59 e	1.09 e	0.83 e
80	0.59 d	1.09 d	2.02 d	1.54 d
160	0.73 c	1.35 c	2.50 c	1.90 c
240	0.96 c	1,78 b	3.29 b	2.50 b
320	1.17 a	2.16 a	3.99 a	3.03 a
SE±	0.028	0.052	0.096	0.077
Phosphorus (kg P/ha)				
0	0.71 b	1.31 b	2.41 b	1.87 b
22	0.77 ab	1.42ab	2.63ab	2.00 a
44	0.81 a	1.50 a	2.78 a	2.11 a
SE±	0.022	0.041	0.076	0.058
Plant density (plants/ha)				
20,000	0.62 c	1.05 c	1.53 c	1.12 c
40,000	0.74 b	1.37 b	2.53 b	1.92 b
60,000	0.92 a	1.80 a	3.75 a	2.89 a
SE±	0.015	0.028	0.052	0.040
Interactions				
N X P	NS	NS	NS	NS
N X D	NS	NS	NS	NS
P X D	NS	NS	NS	NS
NXPXD	NS	NS	NS	NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

4.1.10 Leaf area ratio

The effect of nitrogen and phosporus levels and plant density on leaf area ratio in 1991, 1992 and 1993 is shown in Tables 18, 19 and 20 respectively. Leaf are ratio (LAR) increased from transplanting but then peaked at 6 WAT after which it declined.

The effect of applied nitrogen on leaf area ratio was not significant in the three years and at all periods. However there is a trend of a slight increase up to 160 kg N/ha and there after the LAR decreased.

Phosphorus application also did not significantly influence LAR throughout the study. There was no definite trend of increase or decrease LAR due to phosphorous.

Transplanting pepper at 20,000 plants/ha resulted in significantly higher LAR values at all periods in 1991 and also at 4 and 6 WAT in 1993. LAR was not significantly affected when plant density was further increased to 60,000 plants/ha from 40,000 plants/ha in all the years. At 8 WAT in 1992 LAR was decreased when 20,000 plants/ha was used compared with higher densities. At other periods in 1992 and also at 8 and 10 WAT in 1992 there was no significant difference in LAR between the three densities tested.

There was no significant interaction between the factors on LAR in the years of study.

Table 18 Leaf area ratio (cm^2/g) as affected by nitrogen and phosphorus levels and plant density at different periods in 1993.

Treatment	Leaf area ratio (cm^2/g)			
	4 WAT	6 WAT	8 WAT	10 WAT
Nitrogen(Kg N/ha)				
0	117.25	125.64	109.44	82.50
80	144.40	138.14	122.74	83.88
160	165.00	153.54	117.68	80.00
240	161.07	155.18	90.06	60.07
320	125.95	140.09	79.67	52.22
SE±	22.134	16.001	15.000	14.781
Phosphorus (kg P/ha)				
0	147.55	145.00	112.52	65.80
22	138.54	144.96	96.60	64.10
44	143.85	142.27	92.93	64.38
SE±	17.318	14.126	13.003	11.313
Plant density (plants/ha)				
20,000	186.43 a	191.93 a	135.53 a	88.62 a
40,000	104.69 b	112.50 b	77.66 b	50.26 b
60,000	101.64 b	104.67 b	65.82 b	44.17 b
SE±	15.212	11.200	10.500	10.000
Interactions				
N X P	NS	NS	NS	NS
N X D	NS	NS	NS	NS
P X D	NS	NS	NS	NS
NXPXD	NS	NS	NS	NS

Means within a column of any set of treatment followed by different alphabet(s) are signifcantly different at 5% significance level using DMRT.

Table 19 Leaf area ratio (cm^2/g) as influenced by nitrogen and phosphorus levels and plant density at various sampling periods in 1992.

Treatment	Leaf area ratio (cm^2/g)			
	4 WAT	6 WAT	8 WAT	10 WAT
Nitrogen(Kg N/ha)				
0	85.20	72.55	70.64	46.93
80	139.43	93.53	81.83	70.38
160	128.33	121.58	84.47	71.45
240	102.14	102.41	72.29	56.94
320	96.24	88.00	72.06	53.24
SE±	23.348	19.314	11.520	10.488
Phosphorus (kg P/ha)				
0	105.90	86.43	76.25	51.86
22	92.83	72.07	68.98	56.80
44	92.00	77.76	73.02	60.10
SE±	20.000	16.212	8.314	8.001
Plant density (plants/ha)				
20,000	109.29	75.00	53.78 b	39.38
40,000	75.92	59.76	57.25 ab	47.82
60,000	71.30	77.65	79.76 a	56.04
SE±	19.146	15.000	8.000	6.315
Interactions				
N X P	NS	NS	NS	NS
N X D	NS	NS	NS	NS
P X D	NS	NS	NS	NS
NXPXD	NS	NS	NS	NS

Means in a column of any set of treatments followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

Table 20. Leaf area ratio (cm^2/g) as influenced by nitrogen and phosphorus levels and plant density at various sampling periods in 1993.

Treatment	Leaf area ratio (cm^2/g)			
	4 WAT	6 WAT	8 WAT	10 WAT
Nitrogen(Kg N/ha)				
0	85.27	81.10	78.95	43.88
80	101.38	93.69	92.60	49.26
160	100.40	97.68	95.50	50.25
240	94.29	94.15	92.33	49.11
320	89.39	87.35	85.72	45.75
SE±	9.912	8.760	6.776	5.317
Phosphorus (kg P/ha)				
0	97.60	90.05	89.54	47.47
22	96.27	93.00	90.40	48.25
44	92.83	93.77	91.02	48.35
SE±	8.060	7.152	6.513	4.120
Plant density (plants/ha)				
20,000	116.25 a	107.41 a	83.95	42.71
40,000	75.64 b	73.38 b	72.97	38.57
60,000	69.00 b	67.50 b	76.03	40.91
SE±	7.000	7.000	6.110	3.281
Interactions				
N X P	NS	NS	NS	NS
N X D	NS	NS	NS	NS
P X D	NS	NS	NS	NS
NXPXD	NS	NS	NS	NS

Means in a column of any set of treatments followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

4.1.11 Relative growth rate

Tables 21, 22 and 23 show the effect of nitrogen and phosphorus levels and plant density on relative growth rate in 1991, 1992 and 1993 respectively. In 1991, N levels significantly increased RGR only at 10 WAT compared with control. 80 kg N/ha and 240 at 6 WAT; 80 and 160 kg N/ha at 8 WAT were comparable in RGR. 320 kg N/ha was lower than other levels at 6 WAT but comparable to 240 at 8 WAT and to 240 and 160 kg N/ha at 10 WAT. Application of 160 kg N/ha resulted in highest RGR at 6 WAT in 1992. At 8 WAT 160 was comparable to 80 kg N/ha and higher than 240 and 320 kg N/ha in RGR which were at par. At 10 WAT each level of N increased RGR significantly except 80 kg N/ha which was comparable with the control. In 1993, RGR was significantly affected by N levels only at 6 WAT where application of 80 kg N/ha resulted in the highest RGR compared with other levels. 240 and 320 kg N/ha were similar and significantly lower than 160 kg N/ha and the control in RGR. 160 kg N/ha also resulted in lower RGR compared with the control. The difference between the N levels was not significant at 8 and 10 WAT.

The application of 22 and 44 kg P/ha resulted in higher RGR at 8 and 10 WAT respectively in 1991. The difference between 0 and 44, and 22 was not significant at 8 and 10 WAT respectively. There was no difference between the P levels on RGR at 6 WAT. Applied P at 22 kg P/ha significantly yielded superior RGR values, compared with the control at 8 and 10 WAT in 1992. 22 and 44 at 8 and 10 WAT, 0 and 44 kg P/ha at 8 WAT

were however similar. The levels were also similar at 6 WAT. In 1993 P levels affected RGR only at 6 WAT where 22 kg P/ha out yielded the other levels which were at par.

Relative growth rate significantly decreased when plants were transplanted at 20,000 plants/ha compared with other density levels which were at par at 6 WAT in 1991. However, in 1992, transplanting at 20,000 plants/ha was comparable to 40,000 plants/ha at 6 WAT. RGR in 1991 at 8 and 10 WAT, 8 WAT in 1992 and throughout 1993 was not significantly affected by plant density treatments.

Interaction between the factors was not significant on RGR in all the years.

Table 21. Relative growth rate (g/g/day) as influenced by nitrogen andphosphorus levels and plant density at various sampling periods in 1991.

Treatment	Relative growth rate (g/g/day)		
	6 WAT	8 WAT	10 WAT
Nitrogen(Kg N/ha)			
0	0.31 b	0.20 b	0.09 c
80	0.35 ab	0.20 b	0.14 b
160	0.37 a	0.21 b	0.19 a
240	0.33 ab	0.30 a	0.20 a
320	0.25 c	0.34 a	0.20 a
SE±	0.017	0.013	0.014
Phosphorous (kg P/ha)			
0	0.35	0.20 b	0.19 b
22	0.37	0.28 a	0.22 b
44	0.35	0.23 b	0.26 a
SE±	0.015	0.011	0.012
Plant density (plants/ha)			
20,000	0.31 b	0.25	0.21
40,000	0.35 a	0.25	0.21
60,000	0.35 a	0.27	0.20
SE±	0.010	0.009	0.009
Interactions			
N X P	NS	NS	NS
N X D	NS	NS	NS
P X D	NS	NS	NS
NXPXD	NS	NS	NS

Means in a column of any set of treatments followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

Table 22 Relative growth rate (g/g/day) as influenced by nitrogen and phosphorus levels and plant density at various sampling periods in 1992.

Treatment	Relative growth rates (g/g/day)		
	6 WAT	8 WAT	10 WAT
Nitrogen(Kg N/ha)			
0	0.38 b	0.35 c	0.01 d
80	0.39 b	0.50 a	0.01 d
160	0.75 a	0.50 a	0.02 c
240	0.36 b	0.44 b	0.07 b
320	0.36 b	0.41 b	0.08 a
SE±	0.019	0.016	0.002
Phosphorus (kg P/ha)			
0	0.37	0.34 b	0.02 b
22	0.40	0.38 a	0.03 a
44	0.40	0.36 ab	0.03 a
SE±	0.018	0.013	0.002
Plant density (plants/ha)			
20,000	0.42 a	0.33	0.04 a
40,000	0.40 a	0.34	0.03 b
60,000	0.35 b	0.35	0.01 c
SE±	0.016	0.012	0.001
Interactions			
N X P	NS	NS	NS
N X D	NS	NS	NS
P X D	NS	NS	NS
NXPXD	NS	NS	NS

Means in a column of any set of treatments followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

Table 23 Relative growth rate (g/g/day) as influenced by nitrogen and phosphorus levels and plant density at various sampling periods in 1993.

Treatment	Relative growth rate (g/g/day)		
	6 WAT	8 WAT	10 WAT
Nitrogen(Kg N/ha)			
0	0.34 b	0.31	0.16
80	0.35 a	0.32	0.18
160	0.32 c	0.32	0.18
240	0.31 d	0.32	0.18
320	0.31 d	0.32	0.18
SE±	0.018	0.012	0.014
Phosphorus (kg P/ha)			
0	0.32 ab	0.31	0.17
22	0.35 a	0.32	0.18
44	0.30 b	0.32	0.18
SE±	0.016	0.015	0.012
Plant density (plants/ha)			
20,000	0.30	0.31	0.18
40,000	0.32	0.31	0.18
60,000	0.30	0.31	0.18
SE±	0.016	0.001	0.001
Interactions			
N X P	NS	NS	NS
N X D	NS	NS	NS
P X D	NS	NS	NS
NXPXD	NS	NS	NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

4.1.12 Net assimilation rate

The effect of nitrogen and phosphorus levels and plant density on net assimilation rate is presented in Tables 24, 25 and 26 for 1991, 1992 and 1993 respectively.

Applied nitrogen significantly affected net assimilation rate only at 10 WAT in 1991 and 1992 where application of 320 kg N/ha resulted in the higher NAR compared with other levels. N levels below 240 kg N/ha did not significantly increase NAR over the control in 1992.

Net assimilation rate was not significantly influenced by phosphorus application in all the years.

Significantly higher NAR was obtained at 8 and 10 WAT in 1991 as a result of planting at a density of 60,000 plants/ha compared with less dense populations which were at par statistically. In contrast, transplanting at 20,000 plants/ha resulted in significantly higher NAR compared with higher densities which were similar at 10 WAT in 1992. At other periods in 1991 and 1992 and throughout 1993 no significant difference was observed in NAR due to the densities tested.

There was no significant interaction between the factors on NAR in all the years.

Table 24 Net assimilation rate ($g/cm^2/day$) as influenced by nitrogen and phosphorus levels and plant density at various sampling periods in 1991.

Treatment	Net assimilation rate ($g/cm^2/day$)		
	6 WAT	8 WAT	10 WAT
Nitrogen(Kg N/ha)			
0	0.002	0.002	0.001 b
80	0.003	0.002	0.002 ab
160	0.002	0.002	0.002 ab
240	0.002	0.003	0.003 ab
320	0.002	0.004	0.004 a
SE±	0.0007	0.0008	0.0001
Phosphorus (kg P/ha)			
0	0.002	0.001	0.003
22	0.003	0.002	0.003
44	0.002	0.002	0.004
SE±	0.0008	0.0008	0.0001
Plant density (plants/ha)			
20,000	0.002	0.001 b	0.002 b
40,000	0.003	0.003 ab	0.004 ab
60,000	0.003	0.004 a	0.005 a
SE±	0.0007	0.0008	0.009
Interactions			
N X P	NS	NS	NS NS
N X D	NS	NS	NS NS
P X D	NS	NS	NS NS
NXPXD	NS	NS	NS NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

Table 25 Net assimilation rate ($g/cm^2/day$) as influenced by nitrogen and phosphorus levels and plant density at various sampling periods in 1992.

Treatment	Net assimilation rate ($g/cm^2/day$)		
	6 WAT	8 WAT	10 WAT
Nitrogen(Kg N/ha)			
0	0.004	0.005	0.0001 c
80	0.005	0.006	0.0002 c
160	0.006	0.006	0.0003 c
240	0.004	0.006	0.0010 b
320	0.004	0.006	0.0020 a
SE±	0.001	0.001	0.0002
Phosphorus (kg P/ha)			
0	0.004	0.004	0.0004
22	0.006	0.006	0.0005
44	0.005	0.005	0.0005
SE±	0.0009	0.0008	0.0003
Plant density (plants/ha)			
20,000	0.006	0.006	0.0010a
40,000	0.007	0.006	0.0006 b
60,000	0.005	0.004	0.0002 b
SE±	0.0008	0.002	0.0002
Interactions			
N X P	NS	NS	NS NS
N X D	NS	NS	NS NS
P X D	NS	NS	NS NS
NXPXD	NS	NS	NS NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

Table 26. Net assimilation rate ($g/cm^2/day$) as influenced by nitrogen and phosphorus levels and plant density at various sampling periods in 1993.

Treatment	Net assimilation rate ($g/cm^2/day$)		
	6 WAT	8 WAT	10 WAT
Nitrogen(Kg N/ha)			
0	0.004	0.004	0.004
80	0.004	0.003	0.004
160	0.003	0.003	0.004
240	0.003	0.003	0.004
320	0.004	0.004	0.004
SE±	0.002	0.002	0.001
Phosphorus (kg P/ha)			
0	0.003	0.003	0.004
22	0.004	0.003	0.004
44	0.003	0.003	0.004
SE±	0.002	0.002	0.001
Plant density (plants/ha)			
20,000	0.003	0.003	0.004
40,000	0.004	0.004	0.005
60,000	0.004	0.005	0.004
SE±	0.002	0.002	0.001
Interactions			
N X P	NS	NS	NS
N X D	NS	NS	NS
P X D	NS	NS	NS
NXPXD	NS	NS	NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

4.2 Nutrient Concentration in Shoot as Influenced by Nitrogen and Phosphorus Levels.

4.2.1 Nitrogen

Table 27 shows the effect of nitrogen and phosphorus levels on nitrogen concentration in shoot in 1992 and 1993. Generally lower values of N were recorded at 12 WAT compared with N content at 8 WAT in shoot. At 8 WAt application of 320 kg N/ha resulted in the higher concentration of N.

N concentration with 240 kg N/ha was however similar to that of 320 kg N/ha in 1993, when 240 kg N/ha and the lower rates were statistically same in their N content but significantly higher than the control. In 1992 the difference in N concentration was also not significant when N rate was doubled from 80 kg N/ha to 160 kg N/ha. At 12 WAT applied N at 160 kg N/ha was superior to all other levels of N in terms of N concentration of shoot in both years. N at 320 kg N/ha was comparable to the control and significantly lower than other N levels in both years.

Applied P had a significant effect on N concentration Maximum N concentration was attained on application of 22 kg P/ha at 8WAT in 1993 and in both years at 12 WAT. The two rates of applied P were however similar in their N content at 8 WAT whereas at 12 WAT 0 kg P/ha was significantly similar to 44 kg P/ha in both years.

Table 27. Nitrogen concentration in shoot (%) as affected by nitrogen and phosphorus levels at different periods in 1992 and 1993.

Treatment	Nitrogen concentration in shoot (%)			
	8 WAT		12 WAT	
	1992	1993	1992	1993
Nitrogen (kg N/ha)				
0	2.94 d	2.50 c	2.10 b	2.07 c
80	4.07 b	4.00 b	2.47 a	2.40 b
160	3.96 b	4.00 b	2.53 a	2.60 a
240	3.56 c	4.14 ab	2.38 a	2.35 b
320	4.41 a	4.30 a	2.15 b	2.20 c
SE±	0.071	0.073	0.050	0.048
Phosphorus (kg P/ha)				
0	3.85	3.60 b	2.25 b	2.20 b
22	3.80	3.90 a	2.52 a	2.50 a
44	3.72	3.87 a	2.20 b	2.30 b
SE±	0.055	0.056	0.038	0.044
Interaction				
NXP	XX	NS	XX	NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% significance levels using DMRT.

A highly significant interaction between NxP levels was observed on N concentration in shoot at 8 and 12 WAT in 1992 (Table 28). When nitrogen was not applied (0 kg N/ha) the different P levels did not significantly differ in their N content at 8 WAT. The same trend was observed when the highest rate of N (320 kg N/ha) was used. However, at low rates of N (80 kg N/ha), application of 44 kg P/ha yielded maximum N content in shoot. At 12 WAT, applied P at 44 kg P/ha yielded maximum N content in shoot at 160kg N/ha.

Table 28 Nitrogen concentration in shoot (%) as affected by nitrogen and phosphorus interaction at different periods in 1992.

Treatment	N concentration in short (%)					
	8 WAT			12 WAT		
Phosphorus (Kg P/ha)	0	22	44	0	22	44
Nitrogen (Kg N/ha)						
0	2.94fg	2.26 g	3.12efg	1.75 f	2.80 bc	1.75 f
80	4.00 bc	3.69 d	4.51 a	2.59 cd	2.66 c	2.17 e
160	4.10 bc	4.33 b	3.45 de	2.24 de	2.24 de	3.10 a
240	3.64 d	3.87cd	3.16 ef	2.94 b	2.03 e	2.17 e
320	4.55 a	4.35ab	4.34 ab	1.75 f	2.87 b	1.82 f
SE±	0.124			0.086		

Means within a week followed by different alphabet(s) are significantly different at 1% significance levels using DMRT.

4.2.2 Phosphorus

Phosphorus concentration in shoot was increased significantly by adding 160 kg N/ha in both years at 8 WAT and at 12 WAT in 1993 (Table 29). The rate was however comparable to the control at 8 WAT in 1992, to the control and 80 kg N/ha at 8 WAT in 1993 and to higher levels of N at 12 WAT in the same year. At 12 WAT in 1992 0 kg N/ha and 320 kg N/ha significantly resulted in the highest concentration of P in shoot. Applied N at 80 and 160 kg N/ha however increased P concentration significantly compared with 240 kg N/ha although the two rates were at par with 0 kg N/ha.

Application of 22 kg P/ha resulted in significantly low P concentration at 12 WAT in 1992 compared with other levels. Increasing P level to 44 kg P/ha produced the highest concentration of P in shoot in the two years tested. The highest rate was however comparable to the control in shoot P concentration at 8 WAT and 12 WAT in 1992.

There was a highly significant NxP interaction on shoot P concentration at 8 and 12 WAT in 1992 (Table 30). Highest P concentration was realised on application of 320 kg N/ha in the absence of applied P. The lowest P concentration resulted on a combined application of 240 kg N/ha and 44 kg P/ha at 8 WAT. At 12 WAT the trend was reversed on application of 320 kg N/ha in the absence of P resulted in the lowest p concentration while maximum P concentration was obtained at combined 160 kg N/ha and 44 kg P/ha.

Table 29. Phosphorus concentration in shoot (%) as affected by nitrogen and phosphorus levels at different periods in 1992 and 1993.

Treatment	Phosphorus concentration in shoot (%)			
	8 WAT		12 WAT	
	1992	1993	1992	1993
Nitrogen (kg N/ha)				
0	0.43 a	0.37 ab	0.25 ab	0.25 b
80	0.34 b	0.39 ab	0.22 b	0.24 b
160	0.45 a	0.43 a	0.23 b	0.30 a
240	0.38 b	0.35 b	0.18 c	0.27 ab
320	0.34 b	0.35 b	0.29 a	0.24 b
SE±	0.019	0.020	0.013	0.014
Phosphorus (kg P/ha)				
0	0.38 ab	0.37	0.25 a	0.23 b
22	0.36 b	0.34	0.20 b	0.26ab
44	0.42 a	0.40	0.26 a	0.28 a
SE±	0.015	0.014	0.010	0.010
Interaction				
NXP	XX	NS	XX	NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% significance levels using DMRT.

Table 30 Interaction between nitrogen and phosphorus on phosphorus concentration in shoot (%) at 8 and 12 WAT in 1992.

Treatment	P concentration in shoot (%)					
	8 WAT			12 WAT		
Phosphorus (Kg P/ha)						
	0	22	44	0	22	44
Nitrogen (Kg N/ha)						
0	0.20def	0.27bcd	0.29bc	0.40bcd	0.42bc	0.47ab
80	0.22c-f	0.21def	0.24b-e	0.34cde	0.34cde	0.34cde
160	0.16f	0.24b-e	0.31b	0.31de	0.50ab	0.53a
240	0.24b-e	0.16f	0.15f	0.31de	0.41bcd	0.41bcd
320	0.42a	0.17ef	0.27bcd	0.28e	0.33cde	0.41bcd
SE±	0.023			0.033		

Interaction Means within a week followed by different alphabet(s) are significantly different at 1% significance level using DMRT.

4.2.3 Potassium

Application of 240 kg N/ha significantly increased shoot K at 8 WAT in both years (Table 31). The rate was however comparable to 160 kg N/ha in 1993 when all the N levels were similar statistically. Applied N up to 160 kg N/ha did not raise K concentration significantly compared with lower levels but the three levels were less than 320 kg N/ha at 8 WAT in 1992. At 12 WAT there was no significant difference in K concentration between the various N levels.

Lowest K concentration in shoot was obtained on addition of 22 kg P/ha compared with other levels which were similar at 8 WAT in both years. At 12 WAT there was no significant difference in K concentration between the various P levels in both years.

Potassium concentration in shoot was not affected significantly by the interaction between N and P levels in both years.

4.2.4 Calcium

Neither nitrogen levels nor phosphorus rates had any significant influence on calcium concentration in shoot in both years (Table 32).

Interaction between the two nutrients also did not significantly affect calcium concentration in the two years of study.

Table 31: Potassium concentration in shoot (%) as influenced by nitrogen and phosphorus levels at 8 and 12WAT 1992 and 1993.

Treatment	Potassium concentration in shoot (%)			
	8WAT		12WAT	
	1992	1993	1992	1993
Nitrogen (kgN/ha)				
0	2.84c	2.78b	2.84	2.20
80	2.82c	2.85b	2.34	2.30
160	2.74c	2.90ab	2.45	2.34
240	3.58a	3.03a	2.71	2.40
320	3.32b	2.81b	3.04	2.25
SE±	0.072	0.062	0.255	0.061
Phosphorus (KgP/ha)				
0	3.26a	2.91a	2.61	2.26
22	2.71b	2.75b	2.86	2.30
44	3.22a	2.91a	2.37	2.30
SE±	0.055	0.048	0.253	0.054
Interaction				
NXP	NS	NS	NS	NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

Table 32: Calcium concentration in shoot (%) as affected by nitrogen and phosphorus level at 8 and 12WAT in 1992 and 1993.

Treatment	Calcium concentration in shoot (%)			
	8WAT		12WAT	
	1992	1993	1992	1993
Nitrogen (kgN/ha)				
0	0.70	0.67	0.52	0.50
80	0.79	0.62	0.65	0.70
160	0.98	0.79	0.76	0.67
240	1.05	0.77	0.80	0.63
320	1.00	0.71	0.80	0.62
SE±	0.352	0.250	0.266	0.230
Phosphorus (KgP/ha)				
0	0.80	0.80	0.60	0.60
22	1.00	0.70	0.80	0.68
44	1.00	0.63	0.78	0.54
SE±	0.273	0.248	0.211	0.220
Interaction				
NXP	NS	NS	NS	NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

4.2.5 Magnesium

The tendency to maximum concentration of magnesium in shoot was on application of 240kg N/ha in both years (Table 33). The difference between the various N levels was however not significant.

Application of P tended to depress Mg concentration compared with the control. Like N however, no significant difference was observed in Mg concentration due to various P levels.

There was no significant interaction between N and P levels on magnesium concentration in the years tested.

Table 33: Magnesium concentration in shoot (%) as affected by nitrogen and phosphorus levels at 8 and 12WAT in 1992 and 1993, Samaru.

Treatment	Magnesium concentration in shoot (%)			
	8WAT		12WAT	
	1992	1993	1992	1993
Nitrogen (Kg N/ha)				
0	0.73	0.74	0.46	0.40
80	0.76	0.71	0.50	0.46
160	0.97	0.93	0.60	0.56
240	1.04	1.02	0.63	0.58
320	0.91	0.89	0.59	0.54
SE±	0.120	0.110	0.096	0.080
Phosphorus Kg P/ha)				
0	0.94	0.97	0.58	0.55
22	0.93	0.85	0.56	0.51
44	0.80	0.75	0.53	0.45
SE±	0.115	0.100	0.082	0.061
Interaction				
NXP	NS	NS	NS	NS

4.3 Effect of Nitrogen and Phosphorous Levels on Nutrient Concentration in Fruits.

Table 34 shows the effect of N and P levels on nutrient concentration in fruits at 14WAT in 1992. Each incremental N level significantly increased N concentration in fruits up to 240Kg N/ha after which it declined at 320kg N/ha to a value less than that at 160kg N/ha. Maximum N concentration in fruits was obtained on addition of 22kg P/ha. Increasing the P to 44kg P/ha decreased N concentration significantly compared with Okg P/ha.

With the exception of 320Kg N/ha all the nitrogen levels significantly increased P concentration in fruits compared with OKg N/ha. The effect of P levels on P concentration in fruits was not significant.

Concentrations of potassium, calcium and magnesium in fruit were not significantly affected by N levels.
Concentration in fruits was however decreased on application of 22Kg P/ha compared with other P levels which were significantly similar in their K concentration. Both calcium and magnesium concentration were not influenced by P levels.

Table 34: Nutrient concentration (%) in pepper fruits at 14WAT as affected by nitrogen and phosphorus levels in 1992.

Treatment	Nutrient concentration in fruit (%)				
	N	P	K	Ca	Mg
Nitrogen (Kg N/ha)					
0	2.13e	0.35d	3.09	0.08	0.12
80	2.24d	0.46ab	3.17	0.09	0.12
160	2.33b	0.48a	3.26	0.09	0.11
240	2.37a	0.44abc	3.22	0.10	0.12
320	2.31c	0.38cd	3.12	0.17	0.11
SE±	0.002	0.017	0.069	0.040	0.009
Phosphorus (Kg P/ha)					
0	2.31b	0.43	3.24a	0.09	0.12
22	2.32a	0.40	3.06b	0.14	0.11
44	2.21c	0.43	3.22a	0.09	0.12
SE±	0.001	0.013	0.053	0.031	0.008
Interaction					
NXP	**	**	**	NS	NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

The concentrations of N, P and K in fruits were affected significantly at 1% level by an interaction between N and P (Table 35). Maximum N and P concentrations were attained on application of 160Kg N/ha in the absence of P and P at 22Kg P/ha respectively. The lowest N and P contents were also at the same N level of OKg N/ha but at different P levels of 0 0Kg P/ha and 44kg P/ha respectively. When different P levels were compared at the same N level it was discovered that except at 160Kg N/ha when N concentration declined with increasing P levels, at other levels of N highest concentration of N was obtained at 22kg P/ha. Maximum K concentration in fruits was obtained at a combined 240kg N/ha and 22kg P/ha whilst the lowest K concentration resulted from 80kg N/ha in the absence of applied P.

4.4 Nutrient Uptake as Influenced by Nitrogen and Phosphorous Level

The uptake of various nutrients tested in this study as influenced by nitrogen and phosphorus levels is shown in Table 36.

Nitrogen application significantly affected the uptake of N and Ca and the maximum uptake was reached at 160kg N/ha after which it decreased. Phosphorus, potassium and magnesium uptake were not affected by applied N.

Application of P levels increased N and Ca uptake significantly compared with the control. However application upto 44Kg P/ha decreased N and Ca uptake compared with 22Kg P/ha. P uptake was significantly increased only when 44Kg P/ha was applied compared with the control. There was no

significant difference between 0 and 22 in terms of P uptake. The uptake of p was also similar between 22 and 44kg P/ha. The difference in the uptake of potassium and magnesium was not significant the various P levels.

There was a highly significant interaction between N and P levels on the uptake of N and Ca (Table 37). When various N levels were compared at similar P/level; it was found that N uptake increased with N levels in the absence of fertilizer P up to 240kg N/ha whereas on application of 22kg P/ha N uptake increased upto 160kg N/ha after which it declined. N uptake increased with increasing P levels up to 44kg P/ha only when 80kg N/ha was applied. At other levels of N maximum N uptake was reached at 22kg P/ha declining thereafter. Similarly Ca uptake increased with increasing in N levels significantly increased Ca uptake when 22kg P/ha was applied, at other levels of P Ca uptake was increased up to 160kg N/ha only.

Table 35. Nitrogen x phosphorus interaction as it affected nutrient concentration (%) in pepper fruits at 14WAT in 1992.

Treatment	Nutrient Concentration in fruit (%)								
	N			P			K		
Phosphorus (Kg P/ha)									
	0	22	44	0	22	44	0	22	44
Nitrogen (Kg N/ha)									
0	2.31g	1.85n	2.24h	0.37cd	0.38cd	0.31d	2.92de	3.04cde	3.32bc
80	2.17j	2.45c	2.10 L	0.44bc	0.50ab	0.45bc	2.75e	3.44b	3.32bc
160	2.59a	2.31g	2.09m	0.41bc	0.57a	0.45bc	3.56b	3.00cde	3.20cde
240	2.33f	2.53b	2.26b	0.41bc	0.41bc	0.50ab	3.54b	3.84a	3.28bcd
320	2.13k	2.44d	2.37e	0.38cd	0.31d	0.41bc	3.44b	3.00cde	2.96de
SE±	0.003			0.029			0.119		

Means within a nutrient followed by different alphabet(s) are significantly different at 1% significance level using DMRT.

Table 36: Nutrient uptake (g/plant) as influenced by nitrogen and phosphorus levels at 12WAT in 1993, Samaru.

Treatment	Nutrient uptake (g/plant)				
	N	P	K	Ca	Mg
Nitrogen (Kg N/ha)					
0	7.45e	0.86	9.31	2.32d	2.53
80	10.09b	0.95	10.26	2.28d	2.76
160	12.64a	1.17	8.15	3.61a	4.15
140	9.86c	0.89	6.72	3.32b	4.37
320	9.71d	1.22	13.64	3.13c	3.88
SE±	0.27	0.130	3.56	0.050	0.813
Phosphorus (Kg P/ha)					
0	6.00c	0.70b	6.81	2.18c	2.66
22	12.79a	1.04ab	9.63	3.62a	4.36
44	11.07b	1.31a	12.40	3.00b	3.60
SE±	0.021	0.125	3.00	0.038	0.700
Interaction					
NXP	**	NS	NS	**	NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

Table 37: Interaction between Nitrogen and phosphorous on nutrient uptake (g/plant) at 12WAT in 1993, Samaru.

Treatment	Nutrient uptake					
	N			Ca		
Phosphorus (Kg P/ha)						
	0	22	44	0	22	44
Nitrogen (kg N/ha)						
0	3.76n	11.76f	6.83L	1.51h	2.84e	2.57f
80	5.23m	10.77h	14.28b	1.53h	2.43f	2.89e
160	7.50k	16.53a	13.89c	3.35d	4.24b	3.24d
240	8.38j	12.16e	9.03i	2.42f	4.94a	2.60f
320	5.13m	12.71d	11.30g	2.08g	3.66c	3.66c
SE±	0.046					

Means within a nutrient followed by different alphabet(s) are significantly different at 1% significance level using DMRT.

4.5 Yield Components as affected by Nitrogen and Phosphorus Levels and Plant Density

4.5.1 Number of days to 50% flowering

Figure 7 shows the effect of nitrogen and phosphorous levels and plant density on number of days to 50% flowering in the three years of study.

Number of days to 50% flowering decreased significantly on application of N up to 160Kg N/ha compared with other levels in 1991 (Figure 7A). It took 50% of the plants more days to reach anthesis when N was increased to 240 and 320Kg N/ha. In 1992 application of 160 Kg N/ha resulted in faster flowering compared with other levels. More days were taken to reach 50% flowering when no N was applied and also on application of 320Kg N/ha compared with other N levels. 80 and 240 were significantly comparable in days to 50% flowering. A similar trend was observed in 1993.

Flowering was early on application of 44Kg P/ha in 1991 and 1992 (Fig. 7B) 0 and 22Kg P/ha were similar. Difference was not significant in 1993.

There was also no significant difference in the number of days to 50% flowering due to the various plant densities tested in the three years. (Fig. 7c).

There was also no significance interaction between any of the factors on number of days to 50% flowering.

(C) Plant Density x 000

(B) Kg P/ha

Fig 7: Effect of Nitrogen and Phosphorus Levels and Plant Density on Days to 50% Flowering in Pigeon.

4.5.2 Number of days to maturity

Number of days to maturity decreased with lower levels of N compared with 0kg N/ha in 1991 (Fig. 8A). Higher rates of N (240 and 320kg N/ha) however delayed maturity significantly compared with lower levels. In 1992 and 1993, fruit maturity was significantly delayed in plants without N and those given 80Kg N/ha. Earlier maturity was realised in 1993 by 320Kg N/ha compared with other levels.

Fruits matured earlier when P was applied in 1992 and 1993. (Fig. 8B) whereas fruit maturity was not significantly affected by applied P and 1991.

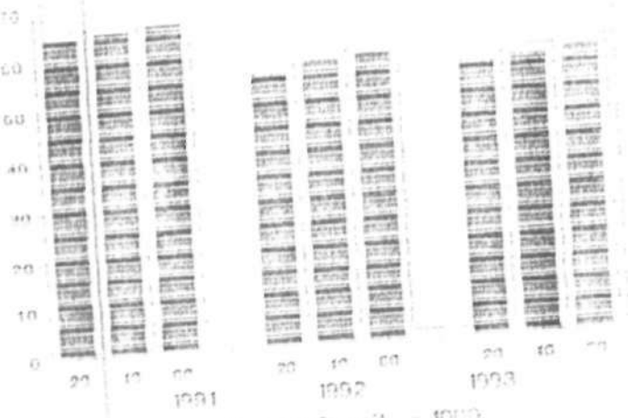
The various plant densities tested did not result in any significant difference in fruit maturity (Fig. 8c). Interaction between the N, P levels and plant density was not significant of number of days to maturity.

4.5.3 Fruit length

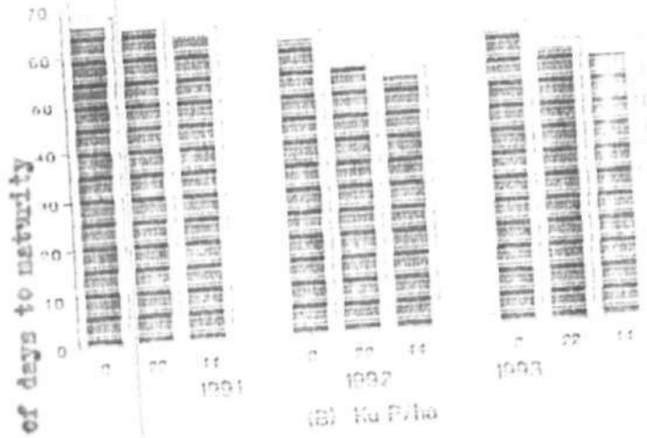
Longer fruits were obtained with each increment in N levels up to 320Kg N/ha in all the years (Figure 9A).

Applied P only increased fruit length when 44 kg P/ha was applied in 1991 (Figure 9B). The difference between 22 and 44kg P/ha was however not significant. In other years applied P did not significantly affect the length of fruits.

Fruit length was also not significantly affected by the three plant densities although there is tendency to shorter fruits with increasing plant density in the three years of study (Figure 9C). Interaction was not significant.



(C) Plant Density x 1000



(B) Kg P/ha

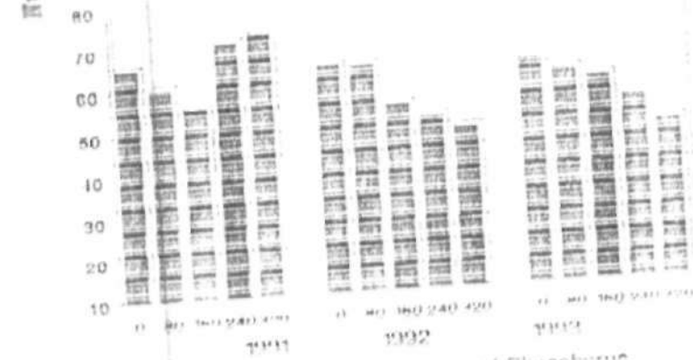


Fig.8. Effect of Nitrogen and Phosphorus Levels and Plant Density on Days to Maturity in Pepper.

(C) Plant Density x 1000

(B) Kg P/ha

Fig 5: Effect of Nitrogen and Phosphorus Levels and Plant Density on Fruit Length in Pumpkin.

4.5.4 Fruit diameter

Nitrogen levels affected fruit diameter in very much the same manner it affected fruit length. Each N level increased fruit diameter significantly up to 320Kg N/ha in all the years (Figure 10A).

Fruit diameter did not significantly differ as a result of phosphorus application in the three years tested (Figure 10B). There was however a tendency of increase in the diameter of fruits from 0 to 44Kg P/ha. The trend was similar in the years tested.

Plant density levels have not significantly affected fruit diameter in all the years (Figure 10C). Fruit diameter however tended to be lower at high density. There was no significant interaction between the factors on fruit diameter in the three years tested.

4.5.5 Number of fruits per plant

Fruit production was stepped up with nitrogen application up to 240kg N/ha after which it declined with the addition of 320kg N/ha in 1991 and 1992 though not significantly (Table 38). In 1991 all the nitrogen rates were at per and significantly yielded more than 0Kg N/ha except 320Kg N/ha. Significantly same number of fruits were recorded when N rate was increased to 320 Kg N/ha from 240 Kg N/ha in 1992 and 1993.

High rate of P significantly yielded more fruits compared were lower levels in 1992 and 1993 (Table 38).

(C) Plant Density x 1000

(B) Kg P/ha

Fig10: Effect of Nitrogen and Phosphorus Levels and Plant Density on Fruit Diameter in Pepper.

Fruit production when 22Kg P/ha was applied did not differ with that obtained when no P was added. In 1991 there was no significant response to P in terms of fruit production.

As plant density increased from 20,000 plants/ha to 40,000 plants/ha and the 60,000 plants/ha, number of fruits produced significantly reduced in 1992 and 1993 (Table 38). Fruit production in 1991 showed a similar trend though however the difference in 1991 did not attain the level of significance.

A significant interaction between nitrogen levels and plant density was observed in 1992 and 1993 (Table 39). When the same plant density was considered under different N levels in 1992, it was discovered that addition of N significantly increased fruit production up to 240Kg N/ha at 60,000 plants/ha with a significant decline at 320Kg N/ha, at other plant densities the decline was not significant. Similarly when ;plant densities were compared at same N levels, number of fruits per plant significantly differ between the plant densities only when 320Kg N/ha was applied. At other levels of N, the difference in fruit production between some of the densities was not significant. In 1993, maximum fruit production was obtained at the lowest density on application of 320Kg N/ha whilst planting at 40,000 plants/ha when no N was added yielded the fewest fruits. Number of fruits/plant was also influenced by a significant interaction between N and P levels in 1993 (Table 40). More fruits were produced at the highest level of both nutrients whereas when no nutrient was

applied the production of fruits was lowest.

Table 38. Effect of Nitrogen and Phosphorus levels and plant density on Number of fruits/plant.

Treatment	Number of fruits/plant		
	1991	1992	1993
Nitrogen (Kg N/ha)			
0	9.30b	5.18d	5.28d
80	21.09a	12.02c	10.63c
160	21.20a	15.72b	15.34b
240	21.60a	20.89a	18.82a
320	15.80ab	20.54a	19.85a
SE±	2.899	0.438	0.337
Phosphorus (Kg P/ha)			
0	17.50	13.51b	13.09c
22	18.40	14.95b	13.76b
44	17.5c	16.15a	15.09a
SE±	2.249	0.339	0.185
Plant density (Plants/ha)			
20,000	21.80	16.22a	15.42a
40,000	15.90	14.99b	14.19b
60,000	15.80	13.40c	12.33c
SE±	2.079	9.125	0.119
Interaction			
NXP	NS	NS	X
NXD	NS	X	X
PXD	NS	NS	NS
NXPXD	NS	NS	NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

Table 39. Number of fruits/plant as affected by Nitrogen x plant density interaction in 1992 and 1993

	Number of fruits/plant					
	1992			1993		
Plant density (plants/ha)						
	20,000	40,000	60,000	20,000	40,000	60,000
Nitrogen (Kg N/ha)						
0	5.98j	5.20j	4.35k	5.96g	5.20 h	5.67gh
80	12.93gh	12.10hi	11.02i	11.86e	10.66f	9.36f
160	17.28def	16.14f	13.74g	17.64c	15.89d	12.48e
240	21.99ab	20.94bc	19.73c	18.91bc	18.43bc	18.11c
320	22.92a	20.56bc	18.15d	21.75a	19.77b	18.02c
SE±	0.414			0.324		

Means followed by different alphabet(s) within a year are significantly different at 5% significance level using DMRT.

Table 40. Number of fruits/plant as affected by Nitrogen x phosphorus interaction in 1993.

Treatment	Number of fruits/plant		
Phosphorus (Kg P/ha)	0	22	44
Nitrogen (Kg N/ha)			
0	5.50i	5.56i	5.77i
80	9.00h	9.98h	12.90g
160	14.39f	15.18ef	16.44de
240	18.39f	18.09bc	18.64bc
370	18.85bc	19.99ab	20.70a
SE±	0.414		

Means followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

4.5.6 Number of Seeds/fruit

Table 41 shows the effect of nitrogen and phosphorus levels and plant density on number of seeds/fruit in all the years of study.

Significantly more seeds/fruits were obtained with increasing N levels up to 320kg N/ha in 1992 and 1993. In 1991 significant increase was obtained upto to 240Kg N/ha only. 0 and 80Kg N/ha and 80 and 160Kg N/ha yielded similar seeds per fruit in 1991.

Application of phosphorus significantly depressed seed production compared with 0Kg P/ha in 1992 and 1993. There was no significant difference in seed production /fruit between the three plant densities in 1991.

Interaction of factors on seed production/fruit was not significant in all the years.

4.5.7 Number of seeds/plant

Each increment in N level significantly increased seeds/plant in 1992 and 1993 (Table 42). In 1991, maximum seeds/plant was obtained on addition of 240Kg N/ha after which it declined at 320Kg N/ha. 80Kg N/ha was comparable to 0, 160 and 320Kg N/ha in seeds/plant in 1991.

Applied P did not significantly affect the number of seeds produced per plant in all the years (Table 42).

Similarly planting density had no significant effect number of seeds per plant throughout the period of study.

Table 41. Number of seeds/fruit as influenced by Nitrogen and phosphorus levels and plant density.

Treatment	Number of seeds/fruit		
	1991	1992	1993
Nitrogen (Kg N/ha)			
0	87.00c	86.50e	84.90e
80	122.00bc	122.10d	122.40d
160	144.00b	145.10c	145.20c
240	292.00a	202.80b	200.10b
320	246.06a	245.80a	249.00a
SE±	19.094	5.014	5.250
Phosphorus (Kg P/ha)			
0	225.00	172.00a	171.90a
22	157.00	155.30b	154.70b
44	154.00	154.10b	154.40b
SE±	31.820	3.883	4.074
Plant density (Plants/ha)			
20,000	212.00	161.20	159.20
40,000	162.00	160.90	162.90
60,000	162.00	159.30	198.80
SE±	31.825	1.88	1.920
Interactions			
NXP	NS	NS	NS
NXD	NS	NS	NS
PXD	NS	NS	NS
NXPXD	NS	NS	NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

Table 42. Number of seeds/plant as influenced by nitrogen and phosphorus levels and plant density.

Treatment	Number of seeds/plant		
	1991	1992	1993
Nitrogen (Kg N/ha)			
0	814.00c	704.00e	632.00e
80	1806.00bc	1457.00d	1290.00d
160	3074.00b	2278.00c	2221.00c
240	6340.00a	3602.00b	3638.00b
320	3312.00b	5037.00a	4850.00a
SE±	606.080	118.740	113.930
Phosphorus (Kg P/ha)			
0	2855.00	2624.00	2628.00
22	2843.00	2521.00	2541.00
44	3510.00	2703.00	2409.00
SE±	469.448	92.008	88.260
Plant density (Plants/ha)			
20,000	3346.00	2635.00	2569.00
40,000	3203.00	2637.00	2656.00
60,000	3699.00	2575.00	2354.00
SE±	509.409	36.067	108.883
Interactions			
NXP	NS	NS	NS
NXD	NS	NS	NS
PXD	NS	NS	NS
NXPXD	NS	NS	NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% level using DMRT.

4.6 Influence of Nitrogen and Phosphorus Levels and plant density on the yield of pepper

4.6.1 Fresh fruit yield/plant

The effect of nitrogen and phosphorus levels and plant density on fresh fruit yield is presented in Table 43.

All the N levels yielded higher than the control. Within N levels 240kg N/ha produced higher yield than all the N levels which were significantly at par in 1991. The yield response during both 92 and 93 was very similar, control yielded lowest, the difference between 80 and 160Kg N/ha being at par was significantly lower than 240 and 320Kg N/ha which were statistically same.

Application of P resulted in superior yields compared with 0Kg P/ha only in 1991. In other years there was no significant difference between the P levels in fresh fruit yield/plant.

Fresh fruit yield/plant was also not significantly affected by variation in plant density in the three years of study.

There was no significant interaction between the three factors on fresh fruit yield/plant in all the years.

Table 43. Fresh fruit yield (g/plant) as influenced by nitrogen and phosphorus levels and plant density.

Treatment	Fresh fruit yield (g/plant)		
	1991	1992	1993
Nitrogen (Kg N/ha)			
0	120.00c	66.70c	62.10c
80	239.00b	118.50b	109.00b
160	256.20b	159.50b	126.50b
240	371.00a	220.50a	201.90a
320	269.00b	254.50a	211.00a
SE±	30.623	15.652	14.059
Phosphorus (Kg P/ha)			
0	186.00b	139.10	129.20
22	278.00a	178.90	154.30
44	289.00a	173.90	149.40
SE±	23.692	14.385	13.140
Plant density (Plants/ha)			
20,000	269.00	174.110	146.10
40,000	249.00	164.60	149.00
60,000	239.00	152.90	132.80
SE±	19.307	12.171	12.235
Interaction			
NXP	NS	NS	NS
NXD	NS	NS	NS
PXD	NS	NS	NS
NXPXD	NS	NS	NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

4.6.2 Fresh fruit yield/ha

Table 44 shows the affect of nitrogen and phosphorous levels and plant density on fresh fruit yield/ha.

Significant increases in yield were obtained up to 240kg N/ha in 1992 and 1993. All the applied N levels resulted in comparable yield that was superior to that obtained when no N was added in 1991. Application of 80kg N/ha also resulted in comparable yields to both 0 and 160kg N/ha although 160kg N/ha significantly out yielded 0kg N/ha in 1992 and 1993.

Applied P significantly increased yield/ha in all the years although there was no significant difference between 22 and 44kg P/ha.

Transplanting at 60,000 plants/ha significantly out yielded other plant densities in the three years studied. Fresh fruit yield resulting from 40,000 plants/ha was comparable to that from 20,000 plants/ha in 1991. In successive years, 40,000 plants/ha out yielded 20,000 plants/ha.

A significant interaction between N and P was recorded on fresh fruit yield/ha in 1992 (Table 45). When different plant densities were compared at the same level of nitrogen it was discovered that when nitrogen was given at the rate of 320 Kg N/ha, 60,000 out yielded 20,000 plants/ha. At other levels of N, there was no difference between the densities tested. Fresh fruit yield/ha also responded to an interaction between plant density and phosphorous levels (Table 46). Highest yield was obtained when 44Kg P/ha was applied at a density of

60,000 plants/ha. At lower densities application of 44kg/ha depressed the yield compared with 22kg P/ha.

4.6.3 Dry fruit yield/plant.

Nitrogen and phosphorus application and variation in plant density significantly influenced dry fruit yield per plant (Table 47.).

In 1991 applied nitrogen significantly out yielded 0kg N/ha although the four rates of nitrogen were comparable. In 1992 and 1993 increase in N rate resulted in yield increase upto 240kg N/ha which is comparable statistically with 320kg N/ha in dry fruit yield.

Phosphorus application resulted in superior yield compared with 0kg P/ha in all the years. The two P rates were at par in the three years of study.

Transplanting at 20,000 plants/ha yielded dry fruits that were superior to 60,000 plants/ha in 1992 and 1993. Yields from 40,000 plants/ha plots were comparable to other densities in 1992 but superior to 60,000 plants/ha in 1993. The three densities yielded comparable dry fruits in 1991.

Interaction between the three factors was also not significant and fruit yield in the three years of study.

Table 44. Fresh fruit yield (tons/ha) as influenced by nitrogen and phosphorus levels and plant density.

Treatment	Fresh fruit yield (tons/ha)		
	1991	1992	1993
Nitrogen (Kg N/ha)			
0	4.80b	2.30c	2.16c
80	9.51a	4.60bc	4.13bc
160	10.43a	6.24b	4.92b
240	11.80a	9.77a	8.05a
320	10.88a	10.07a	8.40a
SE±	0.979	0.8258	0.756
Phosphorus (Kg P/ha)			
0	7.05b	4.82b	4.14b
22	10.45a	7.43a	6.46a
44	10.95a	7.00a	6.05a
SE±	0.759	0.676	0.632
Plant density (Plants/ha)			
20,000	5.88b	3.49c	2.89c
40,000	7.95b	6.58b	5.80b
60,000	14.63a	9.17a	8.00a
SE±	0.731	0.650	0.561
Interactions			
NXP	NS	*	NS
NXD	NS	NS	NS
PXD	NS	*	NS
NXPXD	NS	NS	NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

Table 45. Fresh fruit yield (tons/ha) as influenced by nitrogen x plant density in 1992.

Treatment	Fresh fruit yield (tons/ha)		
Plant Density (Plants/ha)	20,000	40,000	60,000
Nitrogen (Kg N/ha)			
0	2.00g	2.39g	2.80g
80	4.21ef	4.69de	4.90cde
160	5.67cd	6.25c	6.88c
240	9.89ab	9.73ab	9.69ab
320	9.41b	10.06ab	10.74a
SE±	0.394		

Means followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

Table 46. Fresh fruit yield (tons/ha) as influenced by plant density x phosphorus interaction in in 1992.

Treatment	Fresh fruit yield (tons/ha)		
Phosphorus (KgP/ha)	0	22	44
Plant density (Plants/ha)			
20,000	2.18f	4.45e	3.85e
40,000	4.10e	8.64c	7.02d
60,000	8.20c	9.26b	10.13a
SE±	0.239		

Means followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

Table 47. Dry fruit yield (g/plant) as influenced by nitrogen and phosphorus levels and plant density.

Treatment	Dry fruit yield (g/plant)		
	1991	1992	1993
Nitrogen (Kg N/ha)			
0	38.60b	12.91d	10.68d
80	76.90a	38.15c	32.79c
160	82.30a	51.40b	39.53b
240	97.80a	79.52a	68.53a
320	86.70a	81.85a	69.22a
SE±	7.306	2.810	1.262
Phosphorus (Kg P/ha)			
0	59.90b	40.98b	33.690b
22	80.40a	59.74a	50.55a
44	89.10a	57.58a	48.21a
SE±	5.665	2.402	1.021
Plant density (Plants/ha)			
20,000	81.80	56.15a	45.67a
40,000	76.90	52.96ab	45.30a
60,000	70.80	49.19b	41.48b
SE±	4.880	0.983	0.699
Interactions			
NXP	NS	NS	NS
NXD	NS	NS	NS
PXD	NS	NS	NS
NXPXD	NS	NS	NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

Interaction between the three factors was also not significant in the three years of study.

4.6.4 Dry fruit yield/ha

Dry fruit yield/ha was significantly affected by the three factors studied in all the years. (Table 48).

A progressive increase in dry fruits was obtained with each additional N level in 1992. In 1993 yield increases were significant up to 240kg N/ha whilst in 1991 all the N rates yielded comparable dry fruits that were superior to 0kg N/ha.

Maximum dry fruits were obtained on adding 22Kg P/ha in 1992 and 1993 followed by 44kg P/ha. In 1993 the two rates of P significantly out yielded 0kg P/ha though they were at par in dry fruit yield/ha.

Highest dry fruit yield/ha was realised from 60,000 plants/ha plots followed by 40,000 plants/ha and lastly 20,000 plants/ha in 1992 and 1993. In 1991 the difference in yield between 40,000 plants/ha and 20,000 plants/ha was not significant.

An interaction between nitrogen and plant density significantly influenced dry fruit yield/ha in 1992 and 1993 (Table 49). Each additional N level resulted in higher yield when plants were grown at 40 and 60,000 plants/ha in 1992 whereas at 20,000 plants/ha comparable yields, were obtained with most N rates. In 1993 increase in N rates significantly raised the yield up to 240kg N/ha irrespective of plant density. In each year maximum yield resulted from 60,000 plants/ha when 320kg N/ha was added whilst the lowest yield was obtained from 20,000 plants/ha and 0kg N/ha.

Table 48. Dry fruit yield (tons/ha) as influenced by nitrogen and phosphorus levels and plant density.

Treatment	Dry fruit yield (tons/ha)		
	1991	1992	1993
Nitrogen (Kg N/ha)			
0	1.55b	0.88e	0.80c
80	3.04a	1.48d	1.29b
160	3.41a	2.01c	1.56b
240	3.87a	2.70b	2.43a
320	3.48a	3.24a	2.63a
SE±	0.315	0.173	0.162
Phosphorus (Kg P/ha)			
0	2.30b	1.00c	0.92c
22	3.33a	2.94a	2.42a
44	3.58a	2.25b	1.90b
SE±	0,244	0.161	0,155
Plant density (Plants/ha)			
20,000	1.93b	1.12c	0.91c
40,000	2.59b	2.12b	1.82b
60,000	4.70a	2.94a	2.49a
SE±	0.246	0,153	0.146
Interaction			
NXP	NS	NS	NS
NXD	NS	*	*
PXD	NS	NS	NS
NXPXD	NS	NS	NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

Table 49. Dry fruit yield (tons/ha) as influenced by nitrogen x plant density interaction in 1992 and 1993.

Treatment	Dry fruit yield (tons/ha)					
	1992			1993		
Plant density (Plants/ha)						
	20,000	40,000	60,000	20,000	40,000	60,000
Nitrogen (Kg N/ha)						
0	0.49i	1.00h	1.15gh	0.33h	1.00fg	1.07f
80	0.83hi	1.55fg	2.07e	0.67gh	1.37ef	1.83d
160	1.10h	2.09e	2.86cd	0.83g	1.59de	2.25c
240	1.60f	2.70d	3.90b	1.39e	2.41bc	3.49a
320	1.69ef	3.20c	4.74a	1.35ef	2.71b	3.82a
SE±	0.134					

Means followed by different alphabet(s) within a year are significantly different at 5% significance level using DMRT.

4.6.5 Seed yield/plant

Table 50 shows the effect of nitrogen and phosphorous levels and plant density on seed yield/plant in the three years of study.

A significant yield increase was obtained with rising N levels up to 320kg N/ha in 1992 and 1993. In 1991 yield increased with addition of N up to 240kg N/ha after which it decreased significantly at 320kg N/ha.

The effect of P addition on seed yield per plant was only significant in 1993 where both rates of applied P resulted in higher yield compared with 0kg P/ha but without any significant difference between them.

Seed yield from 20,000 plants/ha plants was significantly

superior to that obtained from 60,000 plants/ha in the three years. 40,000 plants/ha also out yielded 60,000 plants/ha in 1992 and 1993 but yielded less than 20,000 plants/ha in 1991 and 1992. There was no significant interaction between the factors on seed yield/plant in the three years of test.

4.6.6. Seed yield/ha

All the three factors caused a significant response in seed yield/ha (Table 51).

Nitrogen application caused a progressive rise in seed yield up to 320kg N/ha in 1992 and 1993. In 1991 application of 320kg N/ha resulted in yield reduction compared with 240kg N/ha at which maximum seed yield was attained.

Seed yield was increased by application of 44kg P/ha compared with lower levels which were at par in 1993. In previous years the yield was not significantly influenced by adding phosphorus to the soil.

Increase in population density also progressively increased the yield significantly in 1992 and 1993. In 1991, the yield obtained by transplanting at 20,000 plants/ha was comparable to that obtained at 40,000 plants/ha.

Interaction between the factors did not significantly influence seed yield/ha in the three years of study.

Table 50. Seed yield (g/plant) as influenced by nitrogen and phosphorus levels and plant density.

Treatment	Seed yield (g/plant)		
	1991	1992	1993
Nitrogen (Kg N/ha)			
0	4.93d	4.22e	3.78e
80	10.96c	8.72d	7.72d
160	18.63b	13.64c	13.29c
240	31.87a	21.64b	21.79b
320	20.47b	30.16a	28.96a
SE±	1.943	0.718	0.678
Phosphorus (Kg P/ha)			
0	17.30	15.71	13.83b
22	17.23	15.31	15.16a
44	17.99	16.19	16.34a
SE±	1.504	0.556	0.525
Plant density (Plants/ha)			
20,000	19.25a	16.98a	16.58a
40,000	16.66b	15.79b	15.84a
60,000	16.21b	14.26c	12.90b
SE±	1.01b	0.211	0.417
Interaction			
NXP	NS	NS	NS
NXD	NS	NS	NS
PXD	NS	NS	NS
NXPXD	NS	NS	NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

Table 51. Seed yield (kg/ha) as influenced by nitrogen and phosphorus levels and plant density.

Treatment	Seed yield (Kg/ha)		
	1991	1992	1993
Nitrogen (Kg N/ha)			
0	203.00d	164.30e	148.00e
80	446.00c	320.90d	299.00d
160	747.00b	527.90c	511.00c
240	1226.00a	849.70b	838.00b
320	762.00b	1167.10a	1107.00a
SE±	82.956	26.775	28.991
Phosphorus (Kg P/ha)			
0	664.00	610.00	542.00b
22	670.00	629.00	585.00b
44	697.00	578.80	615.00a
SE±	64.286	10.736	22.489
Plant density (Plants/ha)			
20,000	428.00b	337.00c	332.00c
40,000	555.00b	633.20b	636.00b
60,000	1048.00a	846.80a	774.00a
SE±	44.484	11.096	21.499
Interaction			
NXP	NS	NS	NS
NXD	NS	NS	NS
PXD	NS	NS	NS
NXPXD	NS	NS	NS

Means in a column of any set of treatment followed by different alphabet(s) are significantly different at 5% significance level using DMRT.

4.7 Regression analysis

4.7.1 Fruit yield Vs. levels of nitrogen, phosphorus and plant density

Several polynomial models were fitted to find the most adequate model to explain the yield response to nitrogen levels in the three years of study. Quadratic models were found to give the best fit in 1991 and 1993 whereas the linear model appeared to be adequate in 1992 (Fig. 11A). Pooled observed yield for the three years also had a quadratic relationship with nitrogen levels with maximum yield at N level of 230Kg N/ha.

In 1991 fruit yield progressed linearly with phosphorus addition up to 44Kg P/ha (Fig. 11B). Pooled observed yield as well as the predicted yield in 1992 and 1993 increased up to 25Kg P/ha after which the yield declined.

Fruit yield had a linear association with increasing plant density in the three years of study and also with Pooled observed yield (Fig. 11C).

4.7.2 Seed yield/ha Vs. levels of nitrogen, phosphorous and plant density

When seed yield was regressed on nitrogen levels, a linear relationship was observed in 1991 and 1993 and also with observed Pooled data (Fig. 12A). In 1992 the quadratic component gave the best fit with maximum yield obtained at N level of 170Kg N/ha.

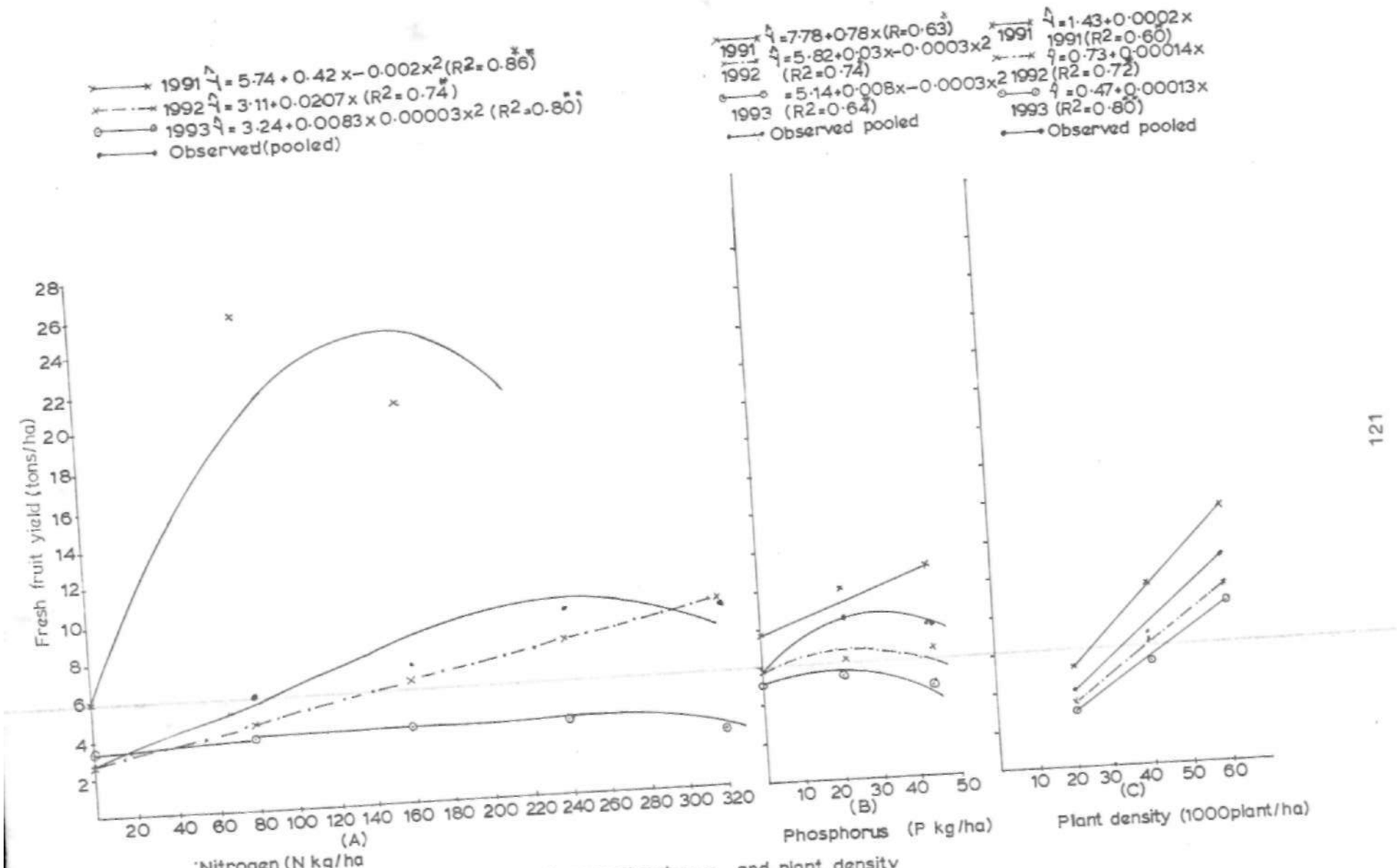


Fig. 11 Regression of fresh fruit yield on nitrogen, phosphorus and plant density

There was a regress in seed yield with addition of P up to 20Kg P/ha after which the yield increased up to 44Kg P/ha in 1992 (Fig. 12B). In 1991 the yield increased linearly with P levels up to 44Kg P/ha. A quadratic fit was however obtained in 1993 and also with Pooled observed data. In each case maximum yield was attained at a P level of 25kg P/ha. Predicted seed yield also responded linearly to increase in plant density in the three years and so also does the pooled observed yield (Fig. 12C).

4.7.3 Fresh fruit yield/ha Vs. concentration of nitrogen and phosphorus in shoot.

Fruit yield was also regressed against nitrogen concentration in shoot (Fig. 13A). A linear relationship between yield and N concentration was observed in both years. The relationship regressed linearly with increase in phosphorus concentration in shoot in the two years.(Fig. 13B).

4.7.4 Nitrogen concentration in shoot Vs. levels of nitrogen and phosphorus

There was quadratic relationship between nitrogen concentration in shoot with nitrogen levels in both years (Fig. 14A). Maximum concentration of nitrogen were recorded at 130 and 270Kg N/ha in 1992 and 1993 respectively.

Nitrogen concentration in shoot also had a quadratic relationship with phosphorus levels in both years (Fig. 14B) Nitrogen concentration decreased with addition of P up to 15 and 20Kg P/ha in 1992 and 1993 respectively.

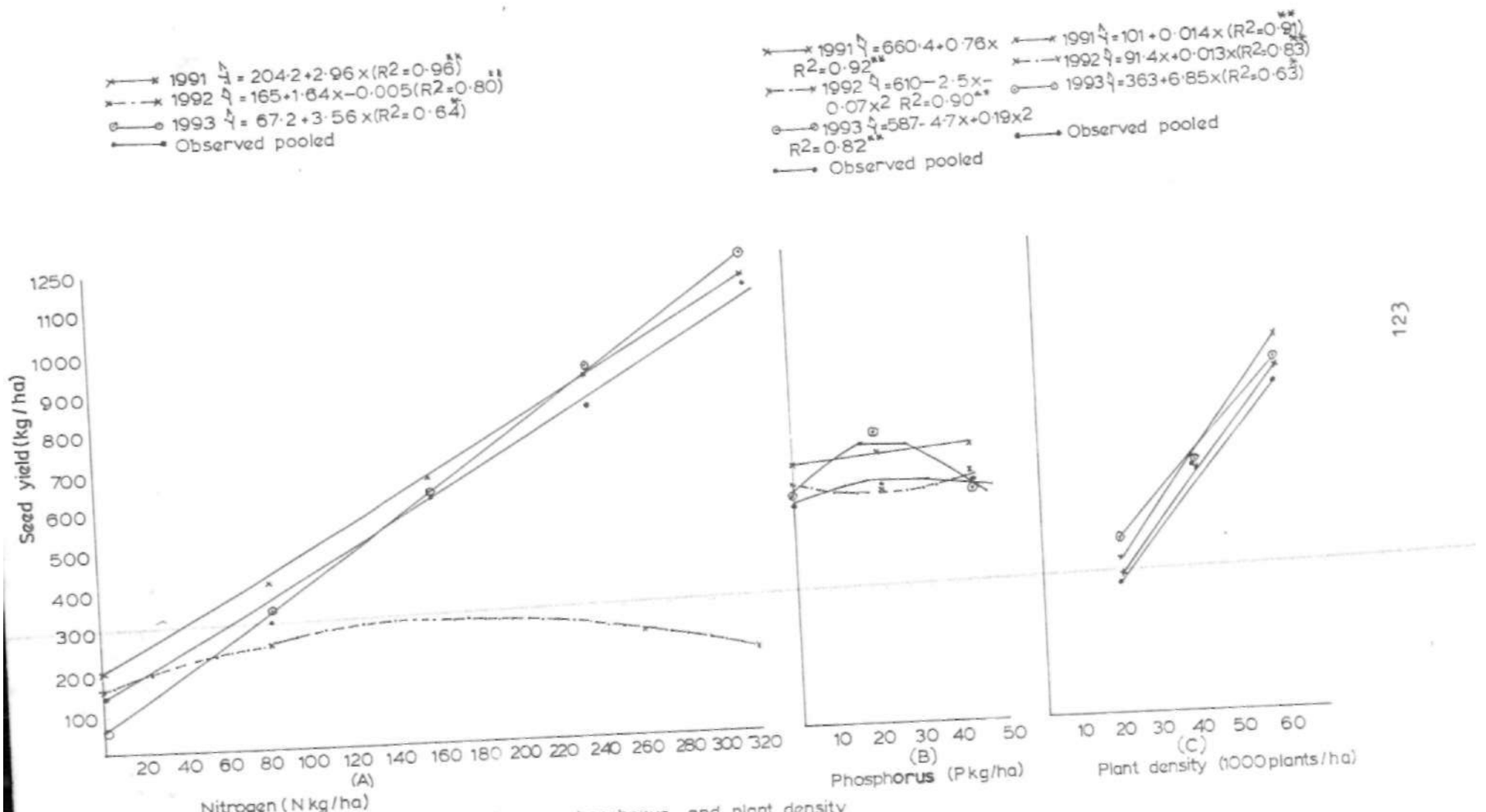


Fig. 12 Regression of seed yield on nitrogen, phosphorus and plant density

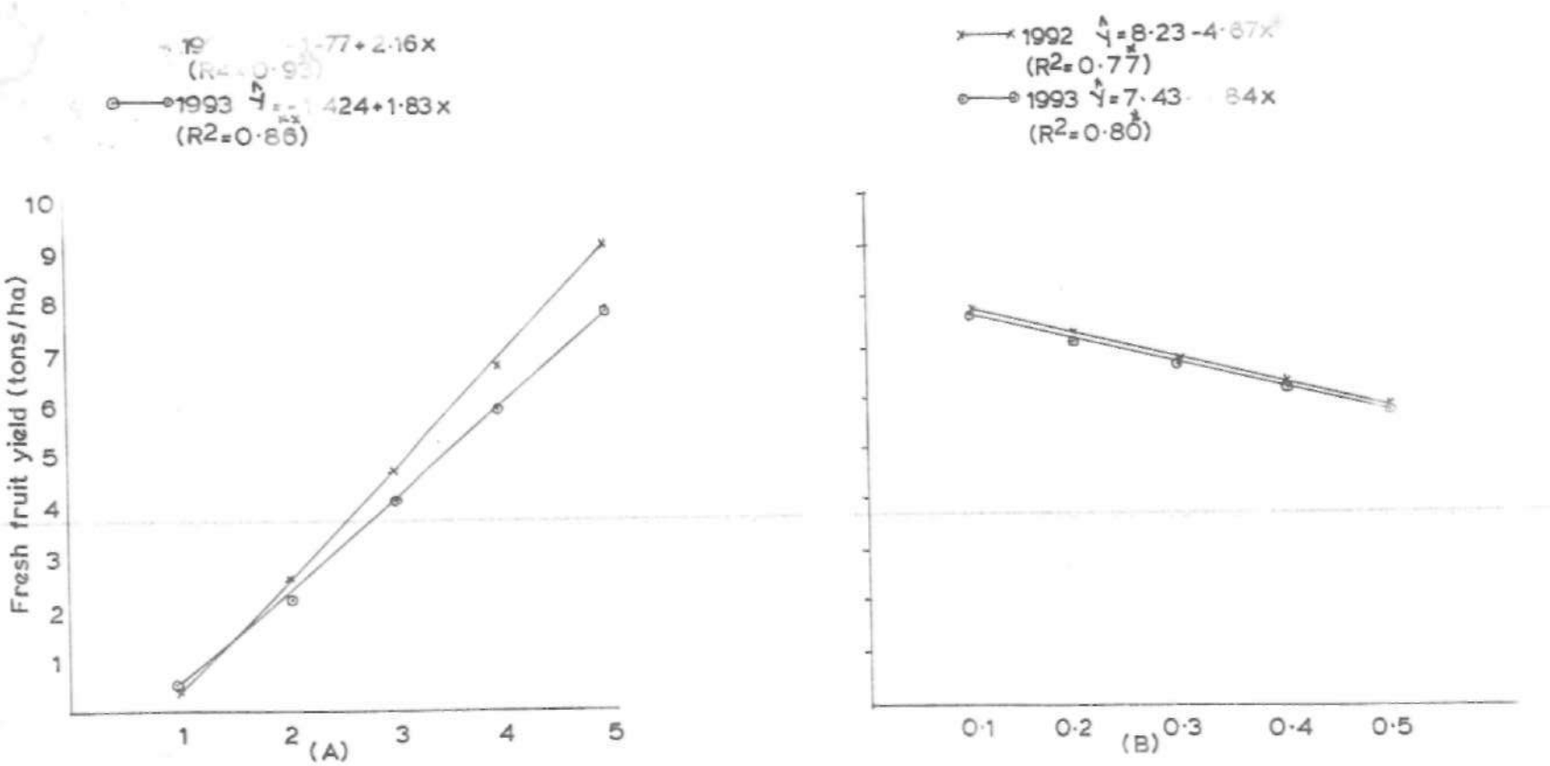


Fig. 13 Regression of fresh fruit yield on nitrogen and phosphorus concentration in shoot (Pooled for 8 and 12 wat

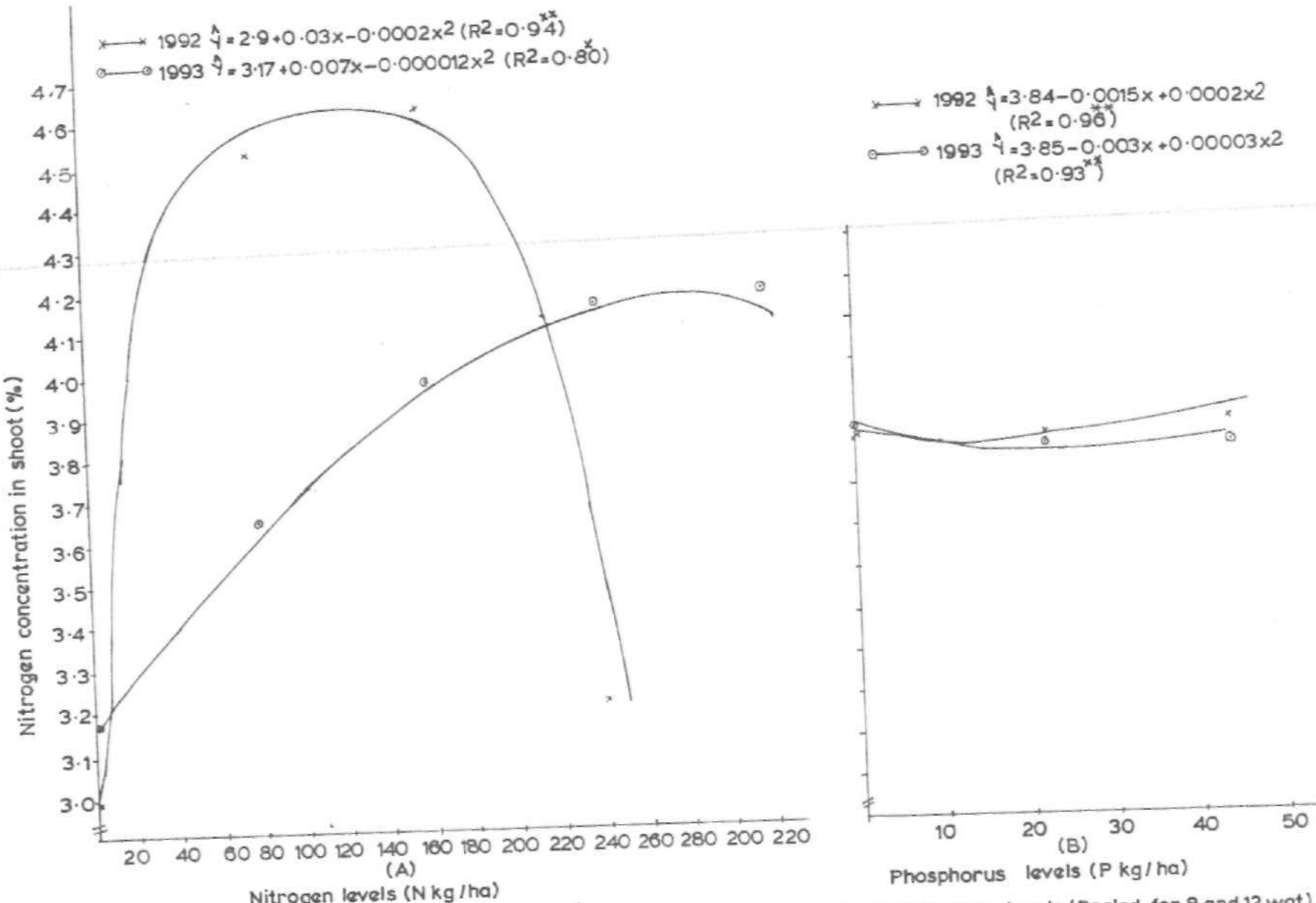


Fig. 14 Regression of nitrogen concentration in shoot on nitrogen and phosphorus levels (Pooled for 8 and 12 wat)

4.7.5 Phosphorus concentration in shoot Vs levels of nitrogen and phosphorus

Relationship between P concentration in shoot and N levels was adequately explained by a regression equation in both years (Fig. 15a). Lowest P concentration were recorded at 80 and 120Kg N/ha in 1992 and 1993 respectively.

Phosphorus concentration reduced with P levels up to 20 and 23Kg P/ha in 1992 and 1993 respectively after which the concentration rose (Fig. 15B).

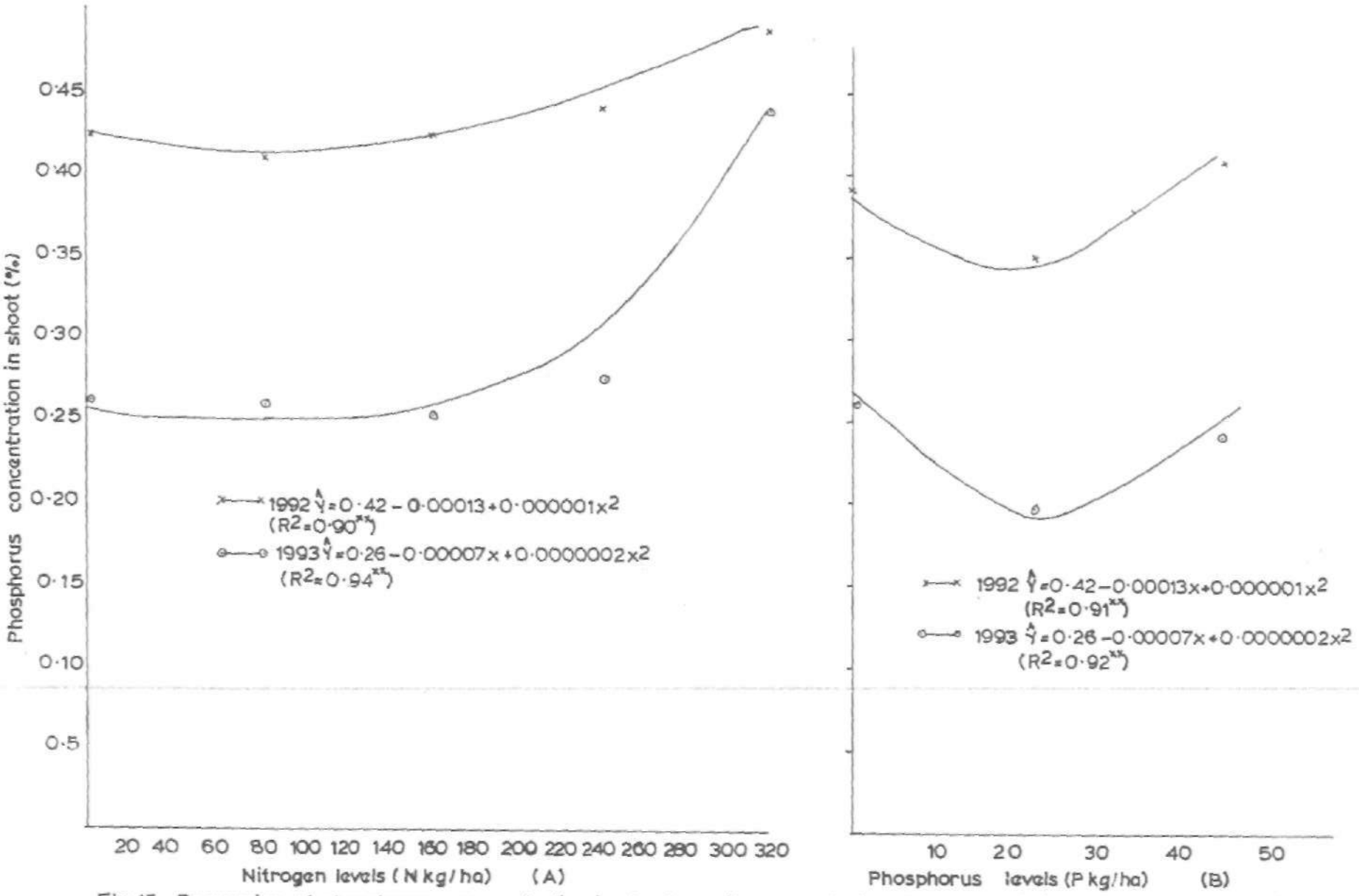


Fig. 15 Regression of phosphorus concentration in shoot on nitrogen and phosphorus levels (Pooled for 8 and 12 wat)

4.8 Correlations and Path coefficient Analysis

4.8.1 1991: Yield and yield component characters

Linear association as measured by the Pearson product moment correlation coefficient or simply referred to as the simple correlation coefficient was computed for various parameters (Table 52). There was a positive and highly significant correlation between fresh fruit yield/ha and dry fruit yield/ha and per plant and seed yield/ha. Positive and highly significant relationships were also observed for dry fruit yield per plant Vs dry fruit yield/ha and seed yield/plant; dry fruit yield Vs seed yield/ha; number of seeds/plant Vs seed yield/plant and per hectare and finally seed yield/plant Vs seed yield/ha. However, number of seeds/fruit was not significantly correlated with any character.

Interrelationships of fresh fruit yield/ha with other parameters were also studied (Fig. 16). Most of the characters had a negative direct contribution towards fresh fruit yield/ha except seed yield/ha.

Table 53 also shows the relative direct and indirect contribution of different characters on fresh fruit yield/ha. The indirect contribution of the characters to yield through number of seeds/plant and seed yield/plant was negative but low. However the indirect contributions of the characters through seed yield/ha was positive and large.

Table 52. Matrix of correlation between yield and some yield component Character in 1991.

	Fresh fruit yield/ha	Dry fruit yield/ plant	Dry fruit yield/ha	Number of seeds/ fruit	Number of seeds/ plant	Seed yield /plant/ha	
1. Fresh fruit yield/ha	1.000						
2. Dry fruit yield/plant	0.663 **	1.000 **					
3. Dry fruit/ha	0.997	0.668	1.000				
4. Number of seeds/fruit	0.008 *	0.026 *	0.007 *	1.000			
5. Number of seeds/plant	0.348 *	0.370 **	0.353 **	0.140	1.000 **		
6. Seed yield/plant	0.338 **	0.518 *	0.342 **	0.242 **	0.567 **	1.000 **	
7. Seed yield/ha	0.573	0.307	0.572	0.172	0.481	0.724	1.000

* Significant correlation at 5% level of significance

** Highly significant correlation at 1% level of significance

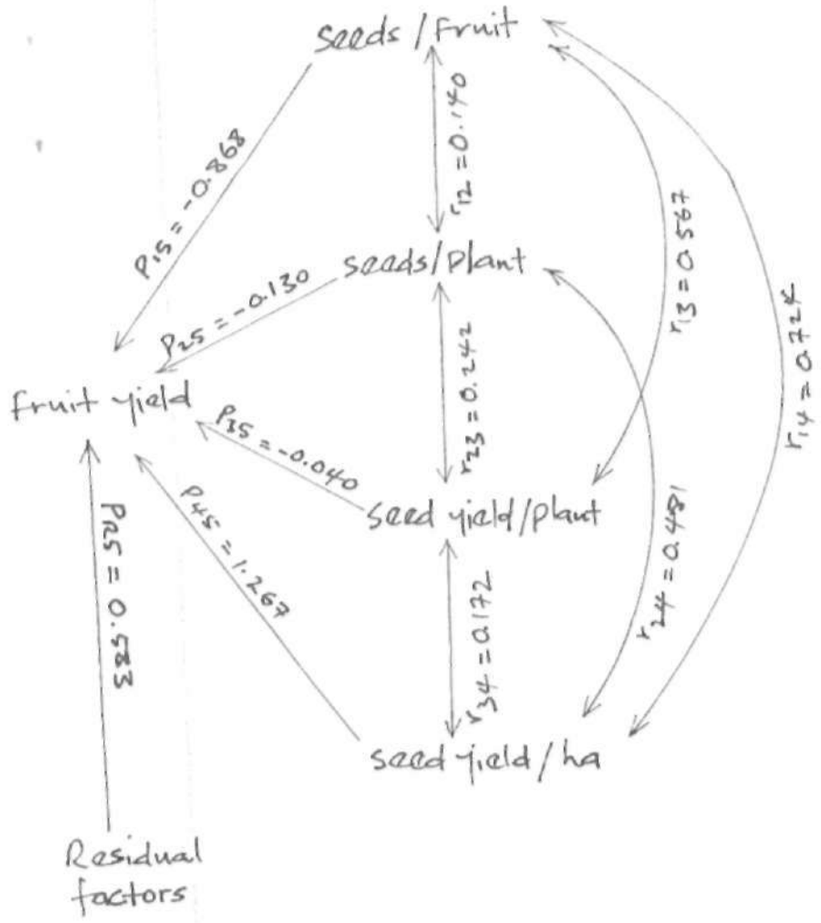


Fig. 16 A path diagram showing relationship between yield and some yield components in 1991.

Table 53. The direct and indirect contributions of different characters on fresh fruit yield in 1991.

Yield attributes	Effect through				
	Number of seeds /fruit	Number of seeds /plant	Seed yield/ plant	Seed yield/ ha	Correlation with yield
Number of seeds/fruit	-0.869a	- 0.018	- 0.023	0.917	0.008
Number of seeds/plant	-0.122	-0.130	-0.010	0.609	0.348
Seed yield/plant	-0.492	-0.031	-0.040	0.902	0.338
Seed yield/ha	-0.628	-0.063	-0.007	1.267	0.573

a) Direct contributions underlined

4.8.2 1992; Growth, yi nd yield component characters

Table 54 shows th various association between some growth and yield characters in 1992. A positive and highly significant linear correlation exist between plant height total dry weight, leaf area index and other yield and yield component characters. Number of branches/plant was not associated with any character except plant height and number of leaves/plant in which a positive significant and highly significant correlations were recorded respectively. Relationship between number of days to 50% flowering and other characters was also not significant. However a significant but negative association exist between days to maturity and other growth and yield parameters.

Table 54. Matrix of correlation between some growth and yield characters in 1992.

	Plant height	Number of leaves	Number of branches	Total dry weight	Leaf area index	Days to 50% flowring	Days to maturity
Plant height	1.000 **						
Number of leaves	0.627 *	1.000 **					
Number of branches	0.332 **	0.443	1.000				
Total dry weight	0.829 **	0.229	0.004	1.000 **			
Leaf Area index	0.773	0.225	0.061	0.760	1.000		
Days to 50% flowering	-0.116 **	-0.188 *	-0.226	0.119 **	0.052 **	1.000	
Days to maturity	-0.777 **	-0.370 *	-0.141	0.700	-0.636 **	0.097	1.000 **
Fruit length	0.907 **	0.347 *	0.169	0.797 **	0.732 **	- 0.091	0.815 **
Fruit diameter	0.911 **	0.320 *	0.156	0.910 **	0.787 **	-0.058	-0.748 **
Number of fruits	0.913 **	0.378 **	0.153	0.877 **	0.689 **	-0.066	-0.798 **
Fresh fruit yield/plant	0.853 **	0.396	0.130	0.919 **	0.780 **	0.089	-0.737 **
Fresh fruit yield/ha	0.534 **	0.098 **	-0.029	0.528 **	0.813 **	0.104	-0.424 **
Dry fruit yield/plant	0.854 **	0.397	0.131	0.919 **	0.780 **	0.088	-0.737 **
Dry fruit yield/ha	0.534 **	0.102	-0.027	0.526 **	0.811 **	0.104	-0.422 **
Number of seeds/fruit	0.789 **	0.192	-0.017	0.887 **	0.813 **	0.228	-0.590 **
Number of seeds/plant	0.852 **	0.277	0.033	0.940 **	0.785 **	0.204	-0.701 **
Seed yield/plant	0.852 **	0.277	0.033	0.940 **	0.785 **	0.204	-0.701 **
Seed yield/ha	0.664	0.045	0.078	0.690	0.846	0.197	-0.508

Interrelationships between fresh fruit yield/ha and some growth characters is presented in Figure 17. The direct contribution of all growth characters towards yield was positive except that of plant height.

When the direct and indirect contributions were partitioned (Table 55), it was discovered that it was only in the case of indirect contribution through plant height that negative values were obtained. Most characters made their greatest contribution to yield through total dry weight with the exception of number of branches/plant which contribute more through plant height and number of leaves/plant.

Similar to 1991 data there was a highly significant and positive correlation between yield and yield component characters in 1992 (Table 56). Infact a perfect direct association was recorded between fresh fruit yield/plant and dry fruit yield/plant.

The path analysis shows that both the mutual and direct contributions to yield was positive (Fig. 18).

Indirect contributions of most parameters through fruit diameter and number of seeds/plant was high and exceed contribution through other attributes and in some cases even direct contributions (Table 57). The total correlation with yield for seed yield/plant and number of seeds/plant was identical although each directly contributed differently.

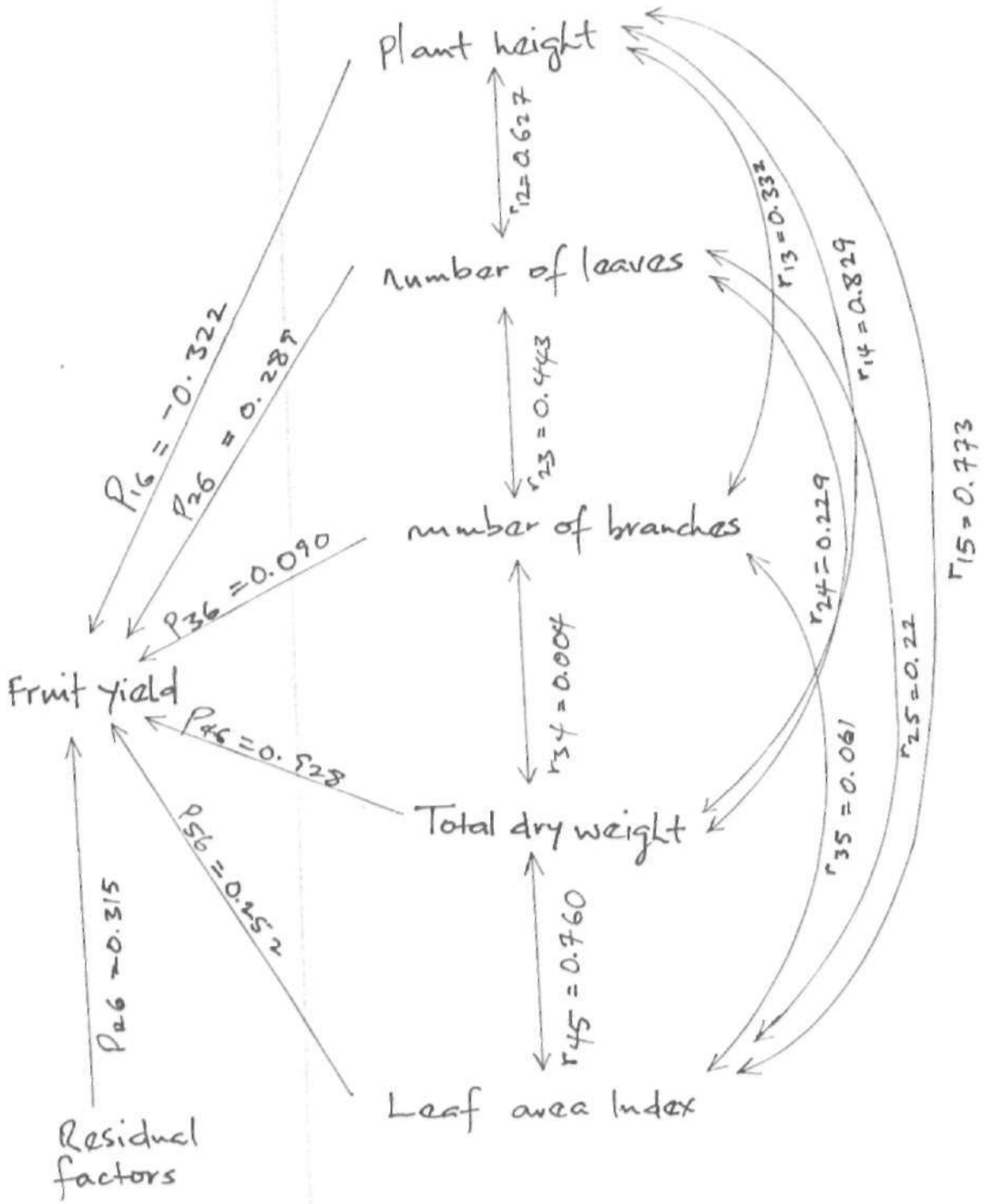


Fig. 17 A path diagram showing relationship between yield and some growth characters in 1992.

Table 55. The direct and indirect contributions of different growth characters on fresh fruit yield in 1992.

Yield attributes	Effect through					
	Plant height	Number leaves	Number of branches	Total dry weight	Leaf area index	Total correlation with yield.
Plant height	-0.322a	0.181	0.030	0.769	0.195	0.853
Number of leaves	-0.202	0.289	0.040	0.213	0.057	0.396
Number of branches	-0.107	0.128	0.090	0.004	0.015	0.130
Total dry weight	-0.267	0.066	0.004	0.928	0.192	0.919
Leaf/area index	-0.249	0.065	0.005	0.705	0.252	0.780

(a) Direct effect underlined.

Table 56. Matrix of correlation between yield and some yield component characters in 1992.

	Fruit length	Fruit diame-ter	No. of fruits/ plant	Fresh fruit yield/ plant	Fresh fruit yield/ ha	Dry fruit yield/ plant	Dry fruit yield/ ha	No. of seeds/ fruit	No of seeds/ plant	Seed yield /plant	/ha
Fruit length	1.000 **										
Fruit diameter	0.846 **	1.000 **									
Number of fruits/plant	0.872 **	0.891 **	1.000 **								
Fresh fruit yield/plant	0.815 **	0.910 **	0.873 **	1.000 **							
Fresh fruit yield/ha	0.499 **	0.913 **	0.429 **	0.608 **	1.000 **						
Dry fruit yield/Plant	0.815 **	0.911 **	0.873 **	1.000 **	0.607 **	1.000 **					
Dry fruit yield/pha	0.499 **	0.513 **	0.424 **	0.608 **	0.999 **	0.607 **	1.000 **				
Number of seeds/fruit	0.724 **	0.840 **	0.761 **	0.855 **	0.615 **	0.895 **	0.615 **	1.000 **			
" " seeds/plant	0.797 **	0.893 **	0.891 **	0.914 **	0.541 **	0.914 **	0.541 **	0.957 **	1.000 **		
Seed yield/plant	0.791 **	0.893 **	0.892 **	0.914 **	0.543 **	0.914 **	0.543 **	0.958 **	0.999 **	1.000 **	
Seed yield/ha	0.621	0.642	0.594	0.687	0.911	0.686	0.911	0.810	0.746	0.748	1.000

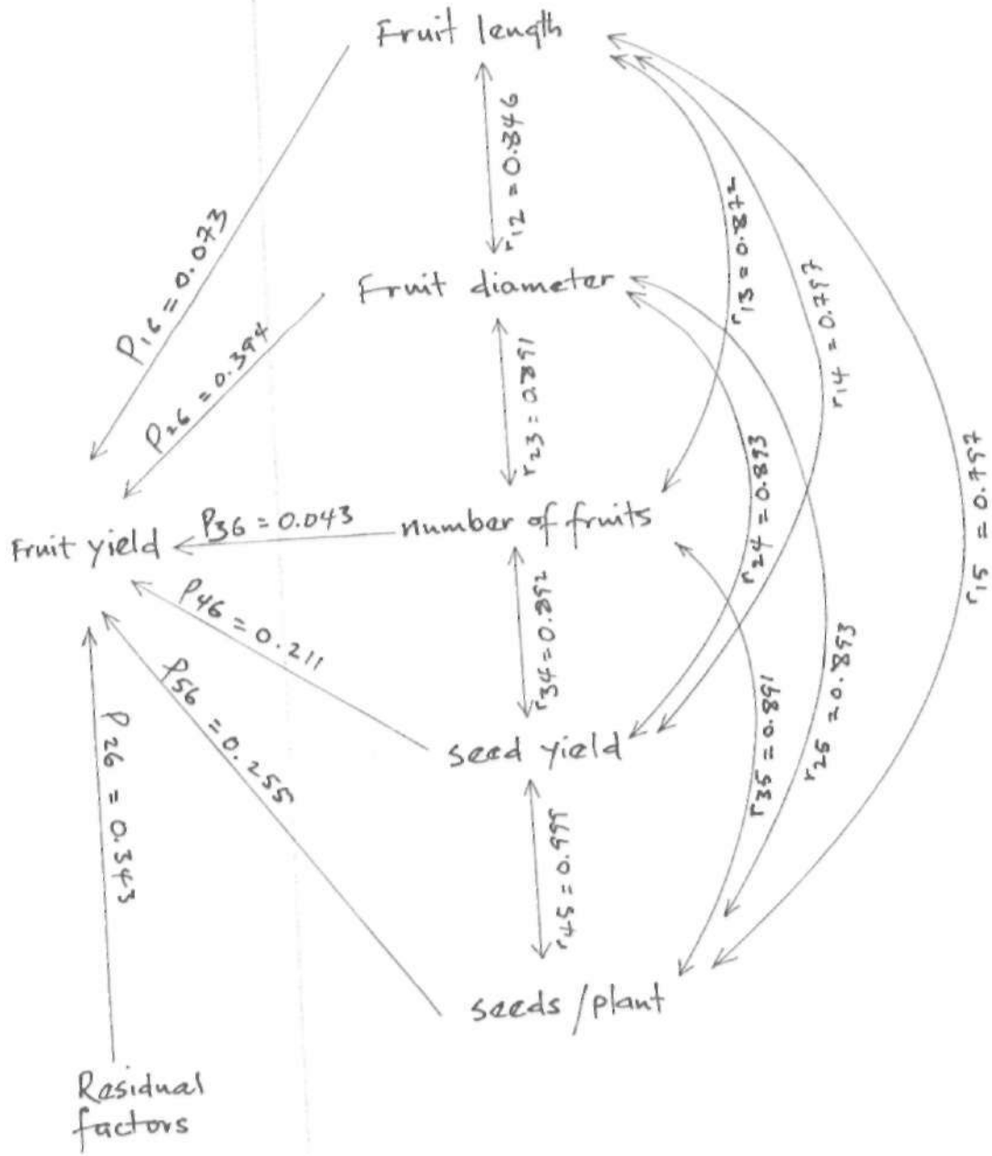


Fig. 18 A path diagram showing relationship between yield and some components in 1992.

Table 57. The direct and indirect contributions of different yield component characters on fresh fruit yield in 1992.

Yield attributes	Effect through					
	Fruit length	fruit diame-ter /plant	Number of fruits /Plant	Seed yield/ plant	Number of seeds Per plant	Total corre-lation with yield
Fruit length	0.073a	0.333	0.037	0.168	0.203	0.815
Fruit diameter	0.062	0.394	0.038	0.188	0.228	0.910
No. of fruits/plant	0.064	0.351	0.043	0.188	0.227	0.873
Seed yield/plant	0.058	0.352	0.038	0.211	0.255	0.914
No of seeds/plant	0.058	0.352	0.038	0.211	0.255	0.914

(a) Direct effect underlined.

4.8.3 1993: Growth yield and yield component characters

A highly significant correlation was observed between plant height, number of branches, total dry weight, leaf area index and days to maturity and other yield and yield component characters in 1993 (Table 58). Associations with days to maturity were negative throughout. Number of leaves/plant was also negatively correlated with other characters.

The path analysis showed considerable direct contribution to yield only by number of branches/plant (Fig. 19). The direct contribution as well as mutual association with other characters in respect of number of leaves/plant was negative.

The indirect contributions of characters through number of leaves/plant and leaf area index is minimal but quite high

in the case of through number of branches/plant and total dry weight (Table 59).

Associations between yield and yield component traits were positive and highly significant (Table 60). A perfect direct correlation was also recorded between fresh fruit yield/plant and dry fruit yield/plant.

Very high direct contributions were observed for number of seeds per plant and seed yield per plant (Fig. 20). Mutual associations between the traits were all positive.

Indirect contribution of characters towards yield were negative through fruit diameter and number of seeds/plant (Table 61). For all characters maximum contributions to yield were made indirectly through seed yield/plant and number of fruits/plant.

Table 58. Matrix of correlation between some growth and yield characters in 1993.

	Plant height	No. of leaves per plant	No. of branches per plant	Total dry weight	Leaf area index	Days to 50% flowering	Days to maturity
Plant height	1.000						
Number of leaves/plant	-0.048	1.000					
Number of branches/plant	0.891**	-0.020	1.000				
Total dry weight	0.894**	-0.189	-0.876**	1.000			
Leaf area index	0.800**	-0.117	-0.799**	0.787**	1.000		
Days to 50% flowering	0.069	-0.459**	-0.131	0.099	-0.131	1.000	
Days to maturity	0.697**	-0.013	-0.655**	0.646**	-0.585**	0.075	1.000
Fruit length	0.920**	-0.164	-0.898**	0.933**	0.807**	-0.014	-0.662**
Fruit diameter	0.925**	-0.023	-0.938**	0.908**	0.819**	-0.135	-0.684**
Number of fruits/plant	0.916**	-0.049	-0.905**	0.850**	0.731**	-0.207	-0.685**
Fresh fruit yield/plant	0.872**	-0.118	-0.903**	0.884**	0.782**	-0.018	-0.683**
Fresh fruit yield/ha	0.526**	-0.293	-0.495**	0.511**	0.775**	0.088	-0.414**
Dry fruit yield/plant	0.872**	-0.118	-0.903**	0.884**	0.782**	-0.018	-0.663**
Dry fruit yield/ha	0.530**	-0.291	-0.497**	0.512**	0.777**	0.085	-0.415**
Number of seeds/fruit	0.834**	-0.190	-0.836**	0.842**	0.779**	0.122	-0.648**
Number of seeds/plant	0.870**	-0.121	-0.882**	0.867**	0.739**	0.002	-0.675**
Seed yield/plant	0.869**	-0.122	-0.887**	0.867**	0.739**	0.001	-0.675**
Seed yield/ha	0.699**	-0.258	-0.680**	0.681**	0.813**	0.063	-0.551**

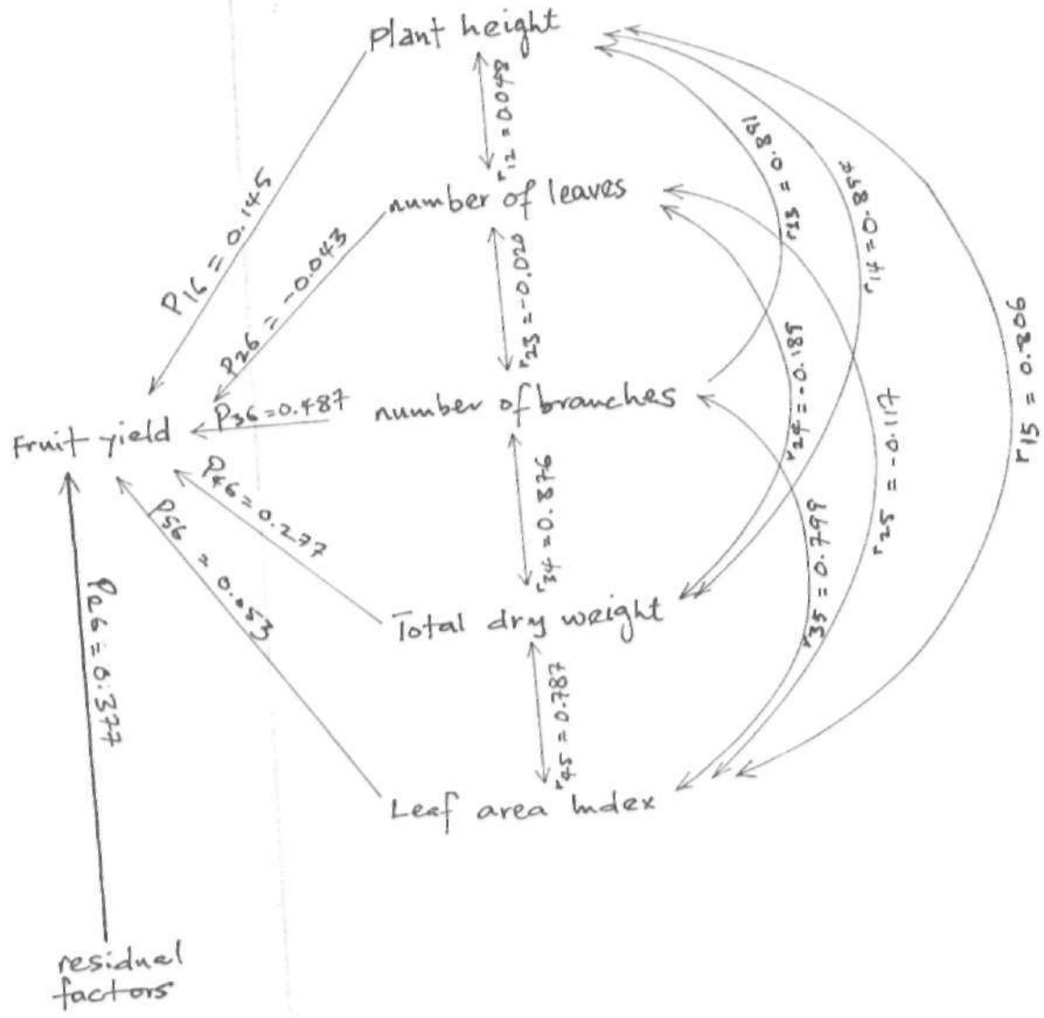


Fig. 19 A diagram showing relationship between yield and some growth characters in 1993.

Table 59. The direct and indirect contributions of different growth characters on yield in 1993

Yield Attributes	Effect through					
	Plant height	No. of leaves/ plant	No. of branches/ plant	Total dry weight	Leaf area index	Total correlation with yield
Plant height	0.145a	-0.002	0.434	0.248	0.042	0.972
No. of leaves/ plant	0.007	-0.043	-0.010	-0.052	-0.006	-0.118
No. of branches/ plant	0.130	0.0009	0.487	0.243	0.042	0.903
Total dry weight	0.130	0.008	0.429	0.272	0.042	0.884
Leaf area index	0.116	0.005	0.389	0.218	0.053	0.782

(a) Direct effect underlined

Table 60. Matrix of correlation between yield and some yield component characters in 1993.

	Fruit length	Fruit diame-ter	No. of fruits/ plant	Fresh fruit yield/ plant	Fresh fruit yield/ ha	Dry fruit yield/ plant	Dry fruit yield/ ha	No. of seeds per fruit per plant	Seed yield per plant per ha.
Fruit	1.000								
Fruit diameter	0.946**	1.000							
Number of fruits/plant	0.894**	0.930**	1.000						
Fresh fruit yield/plant	0.881**	0.885**	0.877**	1.000					
Fresh fruit yield/ha	0.550**	0.513**	0.390**	0.595**	1.000				
Dry fruit yield/plant	0.881**	0.885**	0.877**	1.000	0.595**	1.000			
Dry fruit yield/ha	0.554**	0.517**	0.395**	0.597**	0.999**	0.596**	1.000		
Number of seeds/fruit	0.833**	0.827**	0.813**	0.864**	0.585**	0.864**	0.585**	1.000	
Number of seeds/plant	0.585**	0.863**	0.893**	0.898**	0.477**	0.898**	0.478**	0.906**	1.000
Seed yield/plant	0.585**	0.863**	0.893**	0.898**	0.477**	0.898**	0.477**	0.905**	0.999** 1.000
Seed yield/ha	0.715**	0.689**	0.617**	0.720**	0.874**	0.719**	0.874**	0.780**	0.764** 0.764** 1.000

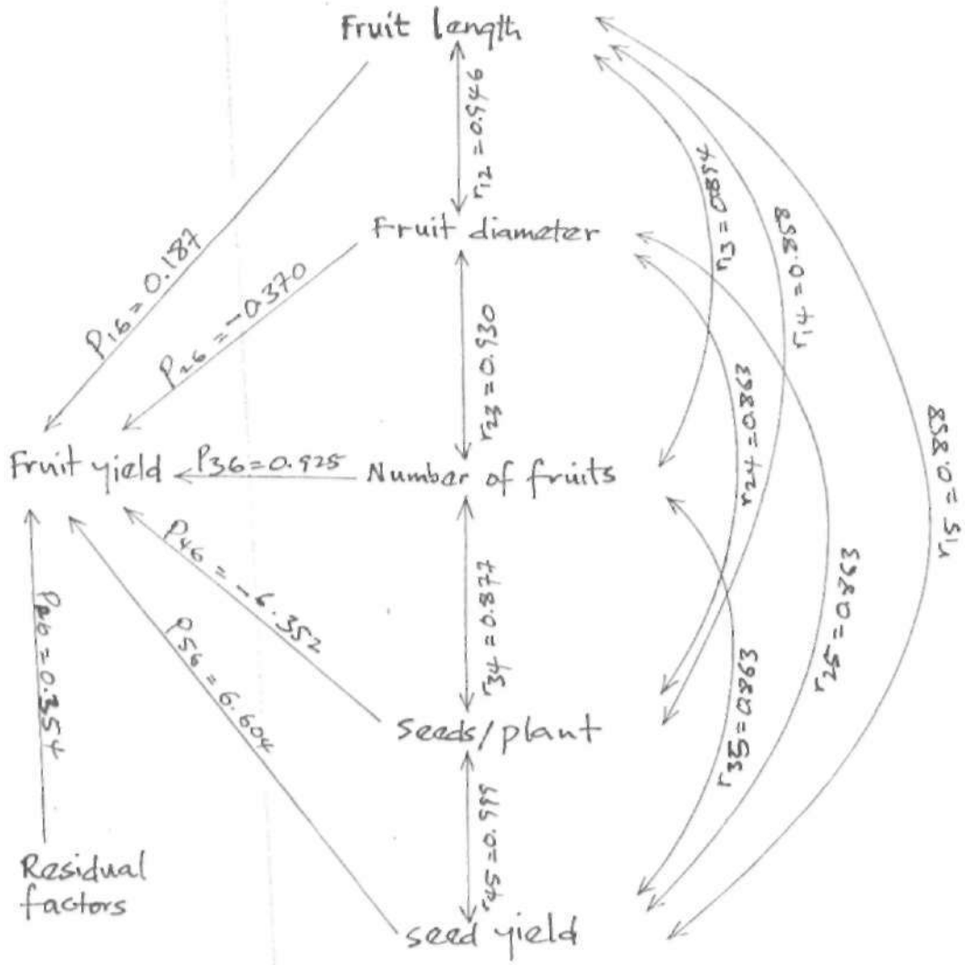


Fig. 20. A path diagram showing relationship between yield and some yield components in 1993.

Table 61. The direct and indirect contributions of different yield component characters on fresh fruit yield in 1992 Samaru.

Yield attributes	Effect through					
	Fruit length	fruit diameter	Number of fruits /plant	Seed yield / plant	Number of seeds/ plant	Total correlation with yield
Fruit length	0.187a	-0.350	0.827	-5.545	5.666	0.881
Fruit diameter	0.177	-0.370	0.860	-5.482	5.699	0.883
No. of fruits/ Plant.	0.167	-0.344	0.925	-5.571	5.699	0.877
Seed yield/ plant	0.160	-0.319	0.811	-6.352	6.597	0.898
No. of seeds/ plant.	0.160	-0.319	0.798	-6.346	6.597	0.898

(a) Direct effect underlined.

4.8.4 Nutrient concentration and uptake

Table 62 shows the correlation between the concentrations of various nutrients in shoot in 1992.

The concentration of N was highly correlated with that of K and Mg negatively and positively respectively. Concentration of N was also negatively correlated with that of P though not significantly. Concentration of K was also significantly and positively associated with that of Mg and P concentration was not linearly related with the other nutrients.

In 1993, in addition to K and Mg, N concentration was also linearly associated with that of Ca and positively so (Table 63), K concentration was also correlated with that of Mg and P, while Ca was associated with Mg and P.

Nitrogen uptake was strongly related with that of P, Ca and Mg (Table 64). Uptake of P: was also correlated with that of K, Ca and Mg. Ca and Mg were linearly associated in their uptake by crop.

Table 62. Matrix of correlation between nutrient concentration in shoot in 1992.

	N	P	K	Ca	Mg
N	1.000				
P	-0.096	1.000			
K	-0.619**	0.154	1.000		
Ca	0.033	0.271	-0.197	1.000	
Mg	0.423**	0.140	0.302*	0.028	1.000

Table 63. Matrix of correlation between nutrient concentration in shoot in 1992.

	N	P	K	Ca	Mg
N	1.000				
P	-0.118 **	1.000 **			
K	-0.509 *	0.621 *	1.000		
Ca	0.333 **	0.360	-0.094 *	1.000 **	
Mg	0.366	0.039	0.392	0.805	1.000

Table 64. Matrix of correlation coefficients between uptake of various nutrient in 1993, Samaru.

	N	P	K	Ca	Mg
N	1.000 **				
P	-0.645 **	1.000 **			
K	-0.268 **	0.716 **	1.000		
Ca	0.614 **	0.356 **	0.263	1.000 **	
Mg	0.703	0.385	0.003	0.799	1.000

4.9 Economic Analysis

Table 65 shows the rates and costs of labour used for production of pepper at Samaru 1991-1993 Pooled data. More labour was used for weeding than any other operation followed by harvesting. Land preparation was mechanized hence the costing was done using tractor hire charges.

Comparison of costs and returns is presented in Table 66. In the absence of nitrogen fertilizer lowest gross returns were obtained inspite of the fact that P was added. In the absence of applied P, maximum gross returns was obtained when 240Kg N/ha was applied. Highest gross returns was obtained when combined 320Kg N/ha and 22Kg P/ha was applied. Combined application of 160Kg N/ha and 22Kg P/ha resulted in the highest net return while 80Kg N/ha and 22Kg P/ha resulted in the highest net return while 80Kg N/ha and 22Kg P/ha fetched the highest return per Naira invested on fertilizer.

4.10 Optimum Level of Nutrients

To calculate the optimum level of nutrients for fruit and seed production the following equations were derived using the Pooled observed data for the three years.

$$Y_f = 1.03+0.008x_N - 0.0048x^2_N$$

$$Y_f = 2.318+0.0081x_p - 0.055x^2_p$$

where

Y_f = predicted dry pepper yield (tons/ha)

X_N = Nitrogen level

X_p = Phosphorous level

$Y_s = 158+1.64x_N - 0.004x_N^2$

$$Y_S = 602+2.49x_p - 0.06x_p^2$$

Where

Y_S = predicted pepper seed yield (Kg/ha)

X_N = Nitrogen level

X_p = phosphorous level

Optimum rate, of nitrogen and phosphorus for fruit yield were 139.76 = 140kg N/ha and 24.56 = 25Kg P/ha respectively.

Optimum rates of nitrogen and phosphorus for seed yield were 202kg N/ha and 20.17kg P/ha respectively.

Table 65. Labour rates and costs in pepper production.

Operation	(a) Labour Required/ha	(b) Cost of labour/ha(N)
Ploughing	Mechanized	500.00
Harrowing	"	500.00
Ridging	"	500.00
Transplanting	15 man-days	300.00
Fertilizer application	11 man-days	220.00
Weeding	90 man-days	1800.00
Re-ridging	20 man-days	400.00
Harvesting	30 man-days	600.00
Total	116 man-days	4820.00

(a) Based on eight-hour working day.

* Average for 1991-1993.

(b) Labour valued at N20.00/man-day.

Table 66. Costs and returns from pepper production with various nitrogen and phosphorous levels (Pooled data for 1991 to 1993.

Treatment		Gross Pepper Value (N)+	Fert. Cost (N)(a)	Total* Cost + Fert. Cost	Net Return	Return/ Naira invested on fertilizer
kg N/ha	kg P/ha					
0	0	6300.001	-	6600.00	-300g	-
0	22	8910.00f	714.00	7415.00	1495.00f	2.09de
0	44	9000.00f	1430.00	8150.00	850.00f	0.59e
80	0	15,120.00e	960.00	7680.00	7440.00e	7.75ab
80	22	21,700.00bc	1675.00	8475.00	13225.00ab	7.89a
80	44	20,340.00cde	2390.00	9210.00	11130.00bcd	4.66bcd
160	0	16,830.00de	1920.00	8720.00	8110.00de	4.22cd
160	22	25,540.00ab	2635.00	9455.00	16085.00a	6.10abc
160	44	23,580.00abc	3350.00	10190.00	13390.00ab	3.99cd
240	0	21,690.00bc	2880.00	9700.00	11990.00bc	4.16cd
240	22	24,570.00ab	3595.00	10435.00	14135.00ab	3.93cd
240	44	25,110.00ab	4310.00	11170.00	13940.00ab	3.23cde
320	0	20430.00cd	3840.00	10680.00	9750.00cde	2.50de
320	22	27,090.00a	4555.00	11415.00	15675.00a	3.44cde
320	44	25650.00a	5270.00	12150.00	13500.00ab	2.56de
SE±		1302.214	-	-	1072.190	1.049

Means in a column followed by different alphabet(s) are significantly different at 5% significance level using DMRT.
+ Cash value based on the retail price of N18.00 per tiya. (N9.00/kg) mid season.
(a) Nitrogen costed at N160.00 per bag (N12.13/kgN) and Phosphorus costed at N130.00 per bag (N32.00/kgP).
*Includes cost of seedlings at N5.00/100 seedlings and cost of labour.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effect of Season

The crop performance as evidenced by the data on growth parameters such as plant height, number of leaves and branches per plant was much higher in 1991 than in the succeeding years. Accumulation of dry matter was also much higher in 1991 than in the following years. This observation could be attributed to the fact that in 1991, seedlings of about seven weeks of age were transplanted out to the field due to certain logistic problems, whereas the seedlings transplanted out in 1992 and 1993 were of the recommended age (five weeks old). Thus the seedlings in 1991 had already grown and had higher initial biomass in terms of dry weight compared with those of 1992 and 1993. Blackman (1919) described plant growth as an example of the operation of compound interest. The growth increment in any period adds to the capital available for subsequent growth. Leaf area, LAI and LAR were also much higher in 1991 than in 1992 and 1993 which have about the same LA, LAI and LAR. However, RGR and NAR recorded lower values in 1991 than in 1992 and 1993. This is probably because when the recording started, the crop in 1991 had already passed the log period of growth. Although normal growth and dry weight accumulation increased from transplanting, peaked at 8WAT and then declined at 10WAT for all the years, RGR declined at 6WAT. This further supports the fact that by the time

recording started for the crop in 1991, the rate of growth had already begun to decline.

Data on nutrient concentration were recorded in 1992 and 1993 only due to the fact that the samples in 1991 were destroyed by rodents. There was very little difference between the years in terms of nutrient concentration, since the seedlings were transplanted out at the same age and the period of sampling were constant for the two years, minimal variation should be expected.

Consequent on transplanting over grown seedlings in 1991, flowering was earlier in that year compared to other years. However, fruit maturity was delayed longer in 1991 than in 1992 and 1993. This could be due to the fact that the balance between vegetative and reproductive growth was skewed towards vegetative growth in 1991 hence the developing fruits had to compete with too much vegetative growth for assimilates thereby lengthening the time it took for fruits to fully develop and mature. The delay in maturity in 1991 could well be the reason for longer and wider fruit in that year compared with succeeding years. Number of fruits produced per plant was also more in 1991 than in 1992 and 1993. Since plant height and branch number were higher in 1991, more loci and surface area was available for the development of fruit buds in the crop in 1991 than in the following years due to sympodial morphology of pepper plant. More fruits with superior length and diameter resulted in higher fruit and seed yields in 1991 compared with succeeding years. However, there

was a low response in yield to N levels in 1991 probably because of the relatively high soil N in that year. Although more rainfall was received in 1993 than in 1992 fruit and seed yield were much better in 1992 than in 1993. This might be due to the longer wet season and better distribution of the rains in 1992 than in 1993.

5.2 Response to nitrogen

Plant height, number of leaves and branches were significantly increased in pepper up to the highest rates at later stages of growth in all the years. At the initial stages of growth there was no difference between the various levels while the high rates even reduced number of branches and leaves at the initial stages of growth in 1992 and 1993. At the tender stage, too much nitrogen may affect crop growth through soluble salt injury as reported by Locascio et al. (1981). Leaf stem and total dry weights were significantly increased with rising nitrogen up to 320kg N/ha. However, the dry weights of bud, flower and fruits were increased up to 240kg N/ha only at 10WAT. Prior to 10WAT the plant was mostly vegetative and the development of reproductive structure was minimal. Since nitrogenous compounds make up a significant part of the total weight of plants, and since increase in nitrogen supply leads to utilization of carbohydrates to form protoplasm and more cells, increased dry weights are quite in consonance with increase in nitrogen application up to the highest rate used in this study.

The yield of reproductive structures were however, obtained at a lower N level compared with vegetative parts. Kraus and Kraybill (1918) recognized that high nitrogen plants were unfruitful or excessively vegetative even though conditions were favourable for carbohydrate synthesis. With some reduction in nitrogen supply, vegetative growth decreased and fruitfulness increased. Hence they concluded that, the maximum yield of reproductive parts was obtained with a lower supply of N than the yield of vegetative parts.

Leaf area per plant and leaf area index were similarly increased with successive fertilizer dressings up to the maximum rate of 320kg N/ha. This could be directly related to increased leafyness with N application as was also reported by Usman (1990), Aliyu and Olarewaju (1994). LAR was however not significantly influenced by N application throughout the period of study. In this study, both the assimilatory materials and the total plant material were significantly affected by N addition. The non significant response in LAR could be due to the constancy in the changes of both assimilatory and plant material with a unit increase in N.

Relative growth rate was also influenced by N levels. Blackman (1919) used the term efficiency index to denote this same concept. Mineral nutrition impinges on all phases of plant growth as pointed out by Leopold (1980) and that nutrient deficiency reduces growth in general and leaf area expansion in particular. The positive influence of N on RGR might be due to the increase in dry matter production with N

application. NAR was only affected by N at 10WAT in 1991 and 1992. Heath and Gregory (1938) reported that NAR was relatively constant for a wide range of species. Watson (1952) concluded that, although there were differences between and within species in NAR, productivity was much more closely related to the leaf area component of growth rate. The variation in NAR at 10WAT due to N in this study could probably be as a result of increased chlorophyll content with N levels. Chandrartna (1964) suggested that under heavy fertilizer application were a dense foliage results and there is a low quantity of light down in the canopy, the chlorophyll content would be more important for total photosynthesis of the population than under less fertile conditions.

Nitrogen levels significantly affected the concentrations of N in shoot and fruit and its uptake by the crop which could indicate that the external N has a profound role in influencing the internal N of the crop. Jones et al. (1964) also reported significant increase in leaf N with N levels but in contrast fruit N was not affected. Miller (1961) reported occurrence of deficiency symptoms in plants having a total N content of 1.26% or less in vegetative tissue whereas in this study plants without fertilizer recorded not less than 2.07% N in their vegetative tissue. The most plausible explanation for this behaviour could be because plants in this study were able to extract some appreciable amount of N from the soil even in the absence of fertilizer N whilst Miller (1961) grew his plants in culture. Phosphorous concentration in shoot was

increased by N application. This is in contrast to the findings of Jones et al. (1964) who reported a decrease in P concentration with N levels. P concentration in fruit was also increased by N levels but there was no significant effect on P uptake due to N levels. The beneficial effect of N levels on P concentration could probably be due to increased solubility and mobility of P and dry matter production with addition of N thus having a cumulative increase in P concentration. Potassium concentration was only affected by N levels at 8WAT a period which might have coincided with active growth of the crop hence the increase in K concentration. Neither K in fruit nor its uptake was however improved significantly by N levels. Similarly calcium and magnesium concentrations were not affected significantly by N levels neither in the shoot nor in the fruit. The concentration of cations in most plant tissues, such as the actively functioning leaves and the fruits, has been reported to be a characteristic of the crop and fairly independent of the soil or fertilization (Russel, 1973). Irrespective of nutrient, concentrations were generally higher at 8WAT than at 12WAT. Allaway (1971) supported by Baldwin (1975) suggested that increased growth over time may dilute the mineral constituents of plant tissues.

There was an elliptical response in number of days to 50% flowering with N levels. Application of 160kg N/ha resulted in the earliest anthesis by plants. Below and above this amount anthesis was delayed. With the pepper, a crop

classified as day-neutral crop (Eguchi, et al. 1958), the flower formation is much affected by nutritional factors. With the pepper, the flower bud were not differentiated unless their growth reached a certain level thus the delay in anthesis with plants receiving low or no N was caused by poor growth. Too much growth has also been reported to delay anthesis as a result of consumption of metabolites by vegetative tissues (Locascio et al. (1981). The high rates of N in this study appeared to have simulated enough vegetative growth to delay flowering. A similar response to N was also shown by days to maturity in 1991. In other years application of N below 160kg N/ha delayed maturity of fruits compared with high levels. This could probably be due to the fact that with low N the growth of the plant would be poor and this could have a negative effect on flowering and eventual fruit set. Fruit length and diameter were increased with N addition up to the maximum rate of 320kg N/ha. This could be directly related to the enhanced photosynthetic surface as a result of N addition and to increased physiological activities leading to more assimilates being produced and subsequently used in rapid increase in fruit size.

Pepper has been reported to produce high percent of blossoms on receiving high N levels when compared with low levels. Such plants also exhibit longer leaf retention and lower flower and fruit abortion thus leading to high fruit set and fruit production (Ozaki and Hamilton, 1954; Addicot and Lynch, 1955). Therefore the increase in number of fruits and seeds

in this study with increase in N levels could be adduced to high flower production and increased fruit setting activity stimulated by the nitrogen levels. The decline in these parameters in 1991 could be attributed to the fact that much of the N was applied during active fruit setting in that year. Due to the increase in fruit and seed number, fruit length and diameter with N levels, fruit yield both fresh and dry and seed yield were also increased. Data from Pooled analysis over season revealed that the optimum N level for seed yield was 320kg N/ha whilst fruit yield was maximized at a lower level of 240kg N/ha. Ozaki and Hamilton (1954) also related increased yield in pepper with N levels to increased fruit setting activity. This is further buttressed by the data on fruit number which showed a reduction in fruit number when N in excess of 240kg N/ha was applied consequently reducing the yield also in 1991. Decline in yield at high rate of N has also been reported by Knavel (1977) 'O' Sullivan (1978) Locascio et al. (1981). While others such as Maynard et al (1962) Batal and Smittle (1981) noted a levelling off of yield only at high levels of nitrogen. Soil types and rainfall obtained during the growing season have also been cited as some of the important factors causing variation in results obtained by different workers.

5.3 Response to Phosphorus

Production of leaves and branches were improved as a result of phosphorus application. Plant height was also increased with phosphorus application. Application of

phosphorous also increased stem, leaf and total dry weights compared with the control. In all cases, increases were not sustained by increasing the rate to 44kg P/ha. This contradicts the findings of Ozaki and Key (1966) who observed increases in growth parameters with P levels up to 246.62kg P/ha. Phosphorous plays a fundamental role in a large number of enzymic reactions that depend on phosphorylation. It is thus essential for cell division and for the development of menglematic tissue, hence its favourable effect on plant growth. The external P requirement of most crops have been found to be within a range of 0.01-0.4ppm P in solution (Fox, 1979). Excess of phosphate over the amount required by the crop sometimes may result in reduction in vegetative growth (Russel, 1973). However, since plants are relatively inefficient users of P in the field (less than 20% of the amount supplied as fertilizers is taken up) (Enwezor, et al. 1989), high rates of P has been used without any appreciable reduction in growth in this study.

Leaf area and leaf area index were increased with each level of P up to 44kg p/ha. Mitchell (1970) reported that application of P increased leaf area particularly in the early stages of growth. The positive effect of applied P on LAI in this study could be directly related to increased leaf number and leaf area. Bouma and Dowling (1966) have reported reductions in leaf area expansion with phosphorous deficiency. Leaf area ratio and net assimilation rate were not statistically affected by application of P. Differences

observed in growth analysis parameters were sometimes judged significant whenever the differences in W and L or A (which were used to derive the growth analysis parameters) were found to be statistically significant. This indirect inference was necessary because normal measures of statistical significance are difficult, if not impossible, to obtain when derivatives of the various growth equations are used to calculate growth analysis parameters (Clawson et al. 1986). RGR was however increased by moderate application of P. This is largely due to increases in leafyness and leaf area. Bouma (1967) reported that under conditions of minimal phosphate (0.25ppm in solution culture) reduced growth, was a consequence of reduced leaf growth.

Maximum concentration of N in both shoot and fruit and its uptake by the crop were attained on application of 22kg P/ha. Jones et al (1964) did not observe any difference in N concentration due to P application. The decrease in N concentration with the higher rate of P could be due to the dilution of nutrient as a result of increased growth. Allaway (1971) has suggested that increased growth resulting from fertilization may dilute the mineral contents of plant tissues. In contrast, application of 22kg P/ha resulted in the lowest concentration of P compared with the control and the higher rate of application. Potassium concentration was also lower on application of 22kg P/ha, the effect was however only significant at 8WAT. Fawausi (1972) similarly reported that at the flowering and fruit set stages, application of P

did not result in any significant difference in leaf P content, and that K content in leaf was not affected throughout by applied P. In this study neither the concentration of Ca and Mg in shoot nor in the fruit was affected by applied P although Ca uptake was maximized at 22Kg P/ha.

Experimental results reviewed by Epstein and Jefferies (1964) and Nielsen (1979) indicated that the level of selectivity in nutrient uptake, translocation and utilization of nutrients by plants are genetically controlled. It is stressed that the efficiency by which a crop utilizes soil as a source of nutrients is improved if genotypes with larger root per unit of plant weight is developed. Through its stimulatory role on root growth, P has enhanced the uptake of more minerals than N in this study.

Phosphorous application has resulted in early flowering in this study. Fruit maturity also elicit a comparable response. An ample supply of phosphorous has been reported to promote rapid development (Black, 1968). Yamashita and Goto (1963) found that differentiation of the first flower Cluster by plants took place at progressively earlier dates as the supply of phosphorous increased. Because of the difference in the rate of development consequent on application of P, plants deficient in P matured late in this study compared with those supplied with P. However, fruit length and diameter were generally not influenced by applied P although the high rate resulted in longer fruits in 1991. Fruit production was not

generally affected by P application. The response of crops to P fertilization usually is greatest early in the season and decreases gradually as maturity is approached (Black, 1968). He thus inferred that the need for additional phosphorous is greater in the early part of the growth cycle then in the latter part. In this study applied P appeared to have influenced vegetative growth more than reproductive structures. This is probably due to the fact that the P supplied prior to transplanting the crop is adequate to produce the maximum growth of vegetative parts. Since the availability of fertilizer P tends to decrease relative to availability of soil P as the season progresses, most of the applied P might have been depleted during vegetative growth with little left during fruit production to cause any significant effect.

Seed production was however depressed by P application. This could be related to the enhanced maturity as a result of application of P. The delayed maturity in the absence of P allowed for the production of more seeds. Although fruit fresh yield/plant and seed yield/plant were not affected by applied P, fruit and seed yield/ha were maximized at 22 and 44kg P/ha respectively. Increased seed yield up to the maximum rate in this study could be attributed to increases obtained in both length and diameter of fruits with P application. Fruit yield was however maximized at lower P level of 22kg P/ha. Excess of phosphate over the amount required by the crop sometimes depresses crop yield (Russell,

1973). This has been attributed to the hastening of the maturation processes and consequent reduction of vegetative growth.

5.4 Response to Plant Density

Plant height and the production of leaves and branches were depressed with a higher planting densities. These results are in consonant with those reported by Silva and Couto (1971), Mezhunts (1979). Yanateva and Elogin (1972) attributed the adverse effect of high population density on crop growth to photosynthetic insufficiency while Topoleski (1967) regarded competition between plants for water and nutrients to be the main cause of reduced growth in dense canopies of plants. The density of 40,000 plants/ha was comparable to the other levels in the parameters stated above which could probably indicate the population to be more balanced than the others.

Leaf area per plant decreased while leaf area index increased with increase in plant density up to the highest density. The decrease in leaf area/plant could also be attributed to photosynthetic insufficiency and to competition between plants for growth factors while increase in LAI with increasing plant density is due to the presence of more plants per area hence more leaves per unit area. However, it is pertinent to note that although LAI increased with plant density, the dry weight and leaf area per plant decreased which could be the reason for the decrease in LAR with

increase in plant density. An inverse relationship has been reported between LAR and dry weights of aerial phytomass (Williams and Joseph, 1976). Nichiporovich (1960) who suggested that an optimal leaf area index is definable for every economic crop has also stated that; maximum LAI does not always yield maximum dry matter production. Both RGR and NAR were increased with increase in plant density. Donald (1961) has held that denser stands, initially have more rapid growth, because they display more photosynthetic surface per unit area of ground and thus synthesize more material. The increase in NAR with increase in plant density in this study could also be related to the LAI (Watson, 1952). Brougham (1956) also found that both percentage of solar radiation interception and rate of dry matter production increased with leaf area development and approached a maximum at similar LAI.

Days to 50% flowering, days to maturity, fruit length and diameter were not significantly affected by variations in plant density in this study. However, there is a tendency to delayed flowering while maturity was earlier with increase in plant density. It has already been stated that pepper flowers only after the growth has reached a certain level (Eguchi et al., 1958). In this study poor crop growth was observed due to high population density hence the delay in flowering. The early maturity recorded could be due to the fact that stressed plants tend to develop faster and reach maturity earlier than unstressed plants. The early maturity observed in this study with increased plant density could account for the smaller

fruit produced at high densities. Although seed production was not affected by the densities tested, more fruits/plant were obtained at lower plant densities and this could be attributed to reduced nutrients and light to plants under high population densities. Higher fruit number of lower densities led to higher fruit and seed yield per plant compared with high population density.

Inspite of the fact that growth, fruit size and number were decreased at high plant densities, fruit and seed yield per hectare were significantly higher at higher densities compared with low density. This could probably be due to the fact that the increase in plant number more than compensated for the decrease in productivity per plant at high densities. Higher yield per ha at high densities could also be related to LAI. Because higher densities display more photosynthetic surface per unit are of ground, they synthesize more assimilates (Donald, 1961).

5.5 Interactions

5.5.1 Nitrogen x phosphorous interaction

At the highest rate of P (44kg P/ha) additional nitrogen levels increased plant height and number of fruits upto the maximum level of 320kg N/ha. This could mean that applied P increased the plant response to high rates of nitrogen levels unlike in the case of concentrations of N in both shoot and fruit where maximum concentration was obtained only in the absence of fertilizer phosphorous. Moderate rates of both nutrients seems to favour the concentration of P and K in

fruit and the uptake of N and Ca.

5.5.2 Nutrients x plant density interaction

At high plant densities the response to added level, increased up to the highest level of application in most parameters. Mitchell (1970) similarly noted that as density is increased the response to an added nutrient will continue to a higher level of application. The implication of this is that as the fertility status of the soil is improved, the density required to give maximum yield will increase.

5.6 Regression Analysis

From the results of the regression analysis, fruit yield was generally maximized at 230kg N/ha while 25kg P/ha appeared adequate. Maximum concentration of N in shoot was found at a range of 130 to 270kg N/ha. Since yield had a linear relationship with N content in shoot it could be deduced that a range of 130 to 270 would also be favourable to the yield. In the case of P concentration a range of 20 to 23 Kg P/ha resulted in the lowest P content in shoot. As the yield linearly regressed with P concentration it can also be inferred that a range of 20 to 23kg P/ha is adequate. Macy (1936) was among the first scientists to suggest a relationship between the sufficiency of a nutrient and its percentage content in the plant. Relationship between nutrient supply and the chemical composition of the plant has also been found useful in predicting fertilizer requirement of crop by Emmert (1941); Ulrich (1952).

A consistent linear relationship was established between

fruit yield and plant density.

Unlike fruit yield, seed yield linearly increased with N levels indicating the maximum N rate to be optimal for seed production. Generally a range of 20-25kg P/ha seems sufficient for seed production. Predicted seed yield also linearly responded to plant density.

Although the yields of fruits and seeds were maximized at the same plant density and similar phosphorous levels, higher nitrogen is generally required for seed production than for fruit production in this study.

5.7 Correlation and Path Coefficient Analysis

Positive and significant relationship was established between most of the characters indicating an interdependency between these characters. As the plant increased in height more nodes, are produced at which branches and leaves are differentiated thus the positive direct association between them. The negative association between days to maturity and other growth characters could probably be due to the fact that as fruits develop in pepper normal growth and development is slowed down. Bereny (1970) reported that as fruits enlarge on the plant, vegetative growth and flower production are inhibited. As the fruits mature, vegetative growth, flowering and fruit - setting again resume (Kato and Tanaka, 1971).

Association between most growth parameters and yield and yield components were also positive and significant indicating such parameters to be important yield determinants. Relationship between yield and yield component characters also

revealed length, diameter and number of fruit to be important yield determinants; this confirms the findings of Ado (1991), Aliyu et al. (1991).

The path analysis showed that most of growth characters considered in this study made their greatest contribution to yield through total dry weight. This is due to the fact that increased dry weight is virtually synonymous with increased photosynthetic surface and thus greater photosynthesis.

Yield component characters made their greatest indirect contribution through number of fruits and seeds/plant. The low value of the residual in such cases could mean that the characters that are most important to the yielding ability of pepper have been considered in the study.

5.8 Economic Analysis

Pepper production without fertilizer application resulted in a net loss as a result of high cost of labour charges. Although application of 320kg N/ha and 22kg P/ha brought in the largest gross returns, higher net returns and returns per naira invested on fertilizer were obtained with combinations of 22kg P/ha with 160kg N/ha and 80kg N/ha respectively. This could be directly related to the increased cost of fertilizer with high rates.

5.9 Optimum Level of Factors

There was a variation in the optimum level of nutrients required by different components of the crop. Whereas total dry matter was maximized at 320kg N/ha and 44kg P/ha fruit and seed yield were optimum at 140kg N/ha and 25kg P/ha; and 202kg

N/ha and 20kg P/ha respectively. Fruit yield was optimised at lower N level compared to the total dry matter because higher nitrogen could cause reductions in fruit set especially if the timing is wrong. In addition high rates of N are prone with excessive vegetative growth which could result in the diversion of assimilates for vegetative growth to the detriment of fruit production and development. Although higher N levels were required for seed production compared with fruit yield due to the higher value of seed, seed yield was optimised at a lower P level than fruit yield. This probably was because high P could hasten maturity and hence detract from increased seed production.

In contrast both fruit and seed yield were increased with increase in plant density up to the highest level of 60,000 plants/ha. This could be attributed to increased plants/area.

SUMMARY AND CONCLUSION

Three field experiments were carried out during the rainy season of 1991-1993 at the research farm of the Institute for Agricultural Research Station at Samaru ($11^0 11'N 07^0 38'E$ and 686m above sea level) to study the effect of five nitrogen levels (0,80,160,240 and 320kg N/ha), three phosphorus levels (0,22 and 44kg P/ha) and three plant densities (20,000, 40,000 and 60,000 plants/ha). A split-plot design with three replications was used. Data were collected on growth, parameters, dry weights which were subsequently used for growth analysis and also analysed chemically to ascertain concentration of nutrient and their uptake, yield and yield component characters.

The data collected were statistically analysed. The yields were further subjected to regression and economic analysis and optimum levels were then calculated.

The results revealed significant differences in plant height, number of leaves and branches, leaf area and LAI due to N levels. Aerial phytomass was significantly increased with increment in N levels up to 320kg N/ha. RGR, NAR were also affected by N levels while LAR was not affected. Concentration of N, P and K were also influenced by N levels while the concentration of Ca and Mg remained unresponsive to levels of N. Yield and yield component characters were also significantly affected by nitrogen application.

Application of phosphorus similarly resulted in increase

in most growth parameters such as plant height, number of leaves and branches while aerial phytomass, leaf area and LAI increased upto the highest rate of 44kg P/ha. LAR, NAR were however not affected significantly by applied P. concentration of N, P and K in shoot were similarly affected by P fertilization. Applied P also affected the fruit content of N and K and the uptake of N and Ca. Days to flowering and maturity were shortened while seed production/fruit was decreased by P levels. Number of seed/plant, the yield of fruits and seeds/plant were not significantly affected by P levels in two of the years tested. Fruit yield/ha was increased as a result of P application while seed yield/ha was affected in only one of the years studied.

Increasing plant density resulted in decreased dry weights and leaf area per plant while LAI, NAR, RGR were all increased. Most yield component characters such as days to flowering, maturity, fruit length and diameter were not significantly affected by the various plant density treatment. Although fruit and seed yield/plant were decreased as the density is increased, the total yield/ha was increased up to 60,000 plants/ha.

Significant interactions between the factors were recorded on most parameters like plant height stem dry weight, concentrations of N and P in shoot, and fruit yield. The result of correlation analysis showed significant association between virtually all the characters studied. The correlation was also positive for most characters although days to

flowering and maturity were negatively correlated with all other characters. Path analysis revealed that indirect contribution of growth characters to yield was highest through total dry weight. Yield component characters contributed more through diameter and number of fruits.

This study has shown that although biological yield was increased with nutrient levels up to the maximum rates tested, economic yield of fruits and seeds was optimum at 140kg N/ha, 25kg P/ha and 202kg N/ha, 20kg P/ha respectively. Maximum biological and economic yields were obtained at the density of 60,000 plants/ha. The nutrient concentration in plant tissue has also proved useful in predicting the levels of N and P for optimum yield. Although most yield components were strongly associated with the yield total dry weight, number and diameter of fruit and seed yield/plant were found to be greatly involved in the contribution of other characters to fruit and seed yield. They also made the greatest direct contribution to the yield. Crop improvement programme or agronomic practices should therefore be geared towards improving these traits with eventual improvement in the yield.

REFERENCES

Abdullahi, A. and Lombin, G. (1978) Long term fertility studies at Samaru Nigeria III. Comparative effectiveness of separate and combined applications of mineral fertilizers and farmyard manure in maintaining soil productivity under continuous cultivation in the savannah, Samaru Misc. paper No. 75, 12pp I.A.R./A.B.U., Zaria. Nigeria.

Addicot, F. and Lynch, R. S. (1955) Physiology of Absicssion Annual Review of Plant Physiology 6 P. 211.

Ado, S. G. (1983) Studies on genetic variability for yield and other vegetative and fruit traits in pepper (Capsicum annuum L.) Unpublished M.Sc. Thesis, Dept. of Plant Science, A.B.U., Zaria P. 66.

Ado, S. G. (1991) Inheritance study in some quantitative traits in three segregating generations of pepper (Capsicum annuum L.) Unpublished Ph.D. dissertion, Plant Science Department, A.B.U., Zaria. P. 133.

Aliyu, L., Ahmed, M.K. and Ado, S. G. (1991). Relationships between some characters in chill pepper (C. frutescens L.) Capsicum Newsletter 10; 47 - 48.

Aliyu, L. and Yusuf, Y. (1991). Response of two chilli pepper (Capsicum frutescens L.) varieties to intra-row spacing and nitrogen levels. Capsicum Newsletter 10; 43 - 44.

Aliyu, L. Olarewaju, J. D. and Ahmed, M. K. (1994) Flowering and fruit set in "Tattasai" pepper as influenced by nitrogen and plant density levels. A terminal report submitted to the Horticultural Crops Res. Prog. I.A.R A.B.U; P 13.

Allaway, W. H. (1971), Feed and food quality in relation to fertilizer used. In. Fertilizer technology and use 2nd ed. Soil Science Soc. Amer. Inc. Madison WI PP 322.

A. O. A. C. (1975). Official method of analysis association of the Official Analytical chemists. 12th edition, Washington D.C., 843 PP.

Bache, B. W. and Rogers, N. G. (1970). Soil Phosphate value in relation to phosphate supply to plants from some Nigerian soils. Journal of Agric Science 74: 383 - 390.

Bajaj, K. C. (1970). Effect of nitrogen and phosphorus levels on nutritive values of sweet pepper (Capsicum annuum L.) "Qualitas plantarum" Plant foods for Human Nutrition 28 (4):

Balasubramanian, V.; Nnadi, L. A.; Lombin, L. G. and Yayock, J. Y. (1979). Fertilizer use in Nigeria II Future prospects and problems. Samaru Conference papers 32 - 35 PP.

Baldwin, J. P. (1975). A qualitative analysis of the factors affecting plant nutrient uptake from the soil. J. Soil Sci. 26: 195 - 206.

Batal, K. M. and Smittle, D. A. (1981). Response of Bell pepper to Irrigation, nitrogen and plant population J. Amer. Soc. Hort. Sci. 106: 259 - 262.

Bereny, M. (1970). Effect of Irrigation on flowering and fruit set of red. pepper. Acta Agron Acad. sci. Hung 19: 398 -401.

Black, C. A. (1965). Methods of Soil Analysis II. Chemical and microbiological properties. American Society of Agronomy. Madison Wisconsin 1972 P.

Black, C. A. (1968). Soil, Plant Relationships. John Wiley and Sons Inc. New York P. 792.

Blackman, V. H. (1919). The Compound Interest law and plant growth. Ann. Bot. 33: 353 - 360.

Boominathan, H.; Moni, L. S.; Rajamoni, A. A. and Krishna, A. M. (1971). A note on the spacing of K.I. chillios (Capsicum annuum L.) Madras Agricultural Journal 58 (6): 520 -522.

Bouyoucos, G. H. (1951). A recalibration of the Hydrometer method for making mechanical analysis of soils. Agronomy Journal 43: 433 - 438.

Bouma, D. and Dowling, E. J. (1966). The Physiological assessment of the nutrient status of the plant with respect to phosphorus, sulphur, potassium, calcum or boron on the pattern of leaf area response following the transfer to different nutrient solutions Aust. J. Agric. Res. 17: 633 - 646.

Bouma, D. (1967). Growth changes of subterranian clover during recovery from phosphorous and sulphur stresses. Aust. J. Biol. Sci. 20: 51 - 66.

Brady, W. C. (1978). The Nature and properties of soils. 8th ed. Macmillan Pub. Co. Inc. New York P. 639.

Bray, R. H. and Kurtz, L. T. (1945). Determination of total organic and available forms of P in soil. Soil Science 59: 39 - 45.

Bremner, H. M. (1965). Total Nitrogen In C.A. Black (ed.) Methods of Soil Analysis Part 2. 1149 - 1178.

Briggs, G. E.; Kidd, F. and West, C. (1920). A quantitative analysis of plant growth, parts I and II. Ann. Appli. Biol. 7: 103 - 123 and 202 - 223.

Brougham, R. W. (1956). Effect of Intensity of defoliation on regrowth of Pasture. Aust. J. Agr. Res. 7: 377 - 387.

Buckly, F. (1938). Umuahia Agricultural Station: Review of work. Third West African Agric. Conf.

Carmer, S. G. and Swanson, M. R. (1973). An Evaluation of Ten Pair wise Multiple comparison procedures by monte carlo. methods. J. Amer. SOc Statistical Assoc. 68: 66 - 74.

Chandrartna, M. F. (1964). Genetics and Breeding of rice Longmans, Green and Co. Ltd, London.

Clawson, K. L.; Specht, J. E.; and Blad, B. I. (1986) Growth Analysis of Soya bean Isoline Differing in Pubescens Density. Agronomy Journal 78: 164 - 172.

Cochran, W. G. and Cox, G. M. (1964). Experimental designs 3rd ed. John Wiley and Sons Inc. New York 6098.

Cope, F. and Hunter, J. G. (1967). Interaction between nitrogen and phosphorus in Agriculture. Phosphorus in Agriculture 46: 1 - 9.

Covarelli, G. (1976). The effect of manuring on the quantitative yield of capsicum, Noristadi Agronomic 10 (3): 178 - 186.

Damke, M. M.; Kawarkhe, V. J. and Patil, C. V. (1988). Effect of phosphorus and potassium on growth and yield of chilli. PKV. Research Journal 12: 110 - 114.

Dempsey, A. A. (1970). Plant density experiments with pienentes. (Capsicum annuum) Agric Exp Station 88p cited in Hort Abst. 1234 1979.

Dennison, F. O. (1961). The value of farmyard manure in maintaining fertility in northern Nigeria. Empire Journal of Experimental Agriculture 33: 330 - 336.

Dewey, D. R. and Lu, K. K. (1959). A Correlation and path co -effecient analysis of crested wheat grass seed production. Agronomy Journal 51: 515 - 518.

Dhar, W. A. and Banerjee, A. K. (1961). Nitrogen and Phosphorus interaction. Proc. natr. Acad. Sci. In. P.3100.

Dharmatti, P. R. and Kulkarni, G. N. (1988). Effect of nutrition, spacing and pickings on seed yield and seed quality in bell pepper. Seed Research 16 (2): 148 - 151.

D'Hoore, J. L. (1964). Soil map of Africa Joint project II communications in Technical cooperation in Africa. Lagos P.300.

Donald, C. M. (1961). Competition for light in crops and pastures. Soc. Exp. Biol. Symp. 15: 282 - 313.

Doyne, H. C. (1937). Green manuring in Southern Nigeria. Emp. J. Expl. Agric. 5: 248 - 293.

Duncan, D. B. (1955). Multiple Range and multiple F-Test Biometrics II: 1 - 42.

Duncan, D. B. (1965). A Bayesian Approach to multiple comparisons. Techometrics. 7: 171 - 222.

Eguchi, T.; Matsumura, T. and Ashingawa, M. (1958). The effect of nutrition on flower formation in vegetable crops Proc. Ame. Soc. Hort Sci. 72: 343 - 352.

Emmert, E. M. (1935). New methods for the determination of the availability of N and P to plants. J. Amer. Soc. Agron. 27: 1 - 7.

Emmert, E. M. (1941). Plant tests as a guide to fertilizer treatments of tomatoes. Proc. Amer. Soc Hort. Sci. 38: 621 - 622.

Enwezor, W. O.; Udo, E. J.; Usorah, N. J.; Ayotade, K. A.; Adepetu, J. A.; Chude, V. O. and Udegbe, C. I. (1989). Fertilizer use and management practices for crops in Nigeria (2) 163 pp.

Epstein, E. and Jeffries, R. L. (1964). The genetic basis of selective Ion transport in plants. Ann. Rev. plant physio.). 15: 169 - 184.

Evans, G. C. (1972). The quantitative analysis of plant growth, Blackwell, Oxford pp.355.

Falusi, A. O. (1987). Economic and Technical Efficiency of fertilizer use in Agricultural Production in Nigeria Proc. National Fertilizer Seminar; 28th - 30th Oct. 1987 Port Harcourt, Nigeria PP. 222 - 238.

Fawusi, M. O. A. (1972). Influence of plant density and time of fertilizer application on growth characteristic, nutrient uptake and yield of tomato. Scientia Horticulturea 7: 329 - 337.

Fox, R. L. (1979). Studies on phosphorus nutrition in the tropics. Soils and fertilizers 1979. 6760.

Garg, J. S. and Bansal, M.G. (1972). Optimum dose of nitrogen for high yielding dwart wheat. Fertilizer News 17 (10): 53 - 55.

Gill, H. S.; Thakur, R. C. and Thakur, T. C. (1974). Effect of Nitrogen and phosphorus application on seed yield of sweet pepper. The ind. J. of Hort. 31 (1): 74 - 78.

Goldsworthy, P. R. and Heathcote, R. G. (1963). Fertilizer trials with groundnuts in northern Nigeria. Emp. J. Expl. Agric. 31: 351 - 366.

Gomez, K. A. and Gomez, A. A. (1984). Statistical Procedures for Agricultural Research 2nd ed. John Wiley and sons, Inc. Singapore DC. 680.

Goodall, D. W. and Gregory, F. G. (1947). Chemical composition of plants as an index of their nutritional status. Tech. comm. No.17 East Malling, Kent V.K.

Govind, S. C. (1979). Controlled-release fertilizer and horticultural applications. Proc. Amer. soc. Hort. Sci 77: 506 - 511.

Gregory, F. G. (1926). The effect of climatic conditions on the growth of barley. Ann. Bot. 40: 1 - 26.

Gunes, D. C. (1959). Effect of nitrogen on the availability of soil and phosphate fertilizer to plants. Adv. in Agronomy 11: 403.

Hartley, K. T. (1937). An explanation of the effects of farmyard manure in Northern Nigeria. Emp. J. Expl. agric. 5: 254 - 263.

Higgins, G. M.; Kinkenberg, K. and Valette, J. (1965). Ferruginous or ferratic? Samaru Agricultural Newsletter 7 (2): 34 - 36.

Heath, O. V. S. and Gregory, F. G. (1938). The constancy of net assimilation rate and it's ecological importance.

Ann. Bot 2: 811 - 818.

Heathcote, R. G. and Stockinger, K. R. (1970). Soil fertility under continuous cultivation in Northern Nigeria. II. Responses to fertilizers in the absence of organic manures. Expl. Agric. 6: 345 - 350.

Hughes, A. P. and Freeeman, P. R. (1967). Growth analysis using frequent small harvests. J. Appl. Ecol. 4: 553 - 560.

IITA (1975). Selected methods for soil and plant analysis. International Institute for Tropical agriculture Ibadan, 44 pp.

Isma, F. I. (1989). Flowering and fruit set in "Tattasai" pepper (Capsicum annuum L.) as influenced by nitrogen nutrition and plant population. Unpublished M.Sc. Thesis. Dept of Plant Science, A.B.U., Zaria.

Jackson, M. L. (1958). Soil Chemical Analysis. Englewood Cliffs, New Jerrey: Prentice - Hall Inc.

Jessup, R. J. (1964). Growing capsicums. Agricultural Gazette N. S. W., 75: 1357 - 60.

Johansson, J. (1978). Effects of nutrient levels on growth, flowering and leaf nutrient content of Green horse Rose. Acta Agric. Scend. 28: 363 - 386.

Jones, M. M. (1971). The maintenance of soil organic matter under continuous cultivation at Samaru, Nigeria. J.Agric. Sci. Comb. 77: 473 - 482.

Jones, M. J. (1973). The organic matter content of the savanna soils of West Africa. J. Soil Sci. 24: 42 - 53.

Jones, M. J. and Wild, A. (1975). Soils of the West African Savannah. Technical Communication No. 55, 246 pp. Commonwealth Bureaux of Soils, Harpenden, Herts.

Jones, R.; Thomas, T. and Heilm, M. D. (1964). Nitrogen and phosphorous content of leaf tissue in relation to sweet pepper yields. Proc. Amer Soc. Hort. Sci. 89: 419 - 425.

Kass, D.C.L. (1978). Polyculture Cropping systems - Review and Analysis. Ithaca, New York Cornell International Agric. Bulletin 32 pp.

Kato, T. and Tanaka, M. (1971). Studies on the fruit setting and development of sweet peppers I. fruiting behaviour. J. Japan Soc. Hort. Sci. 40: 359 - 366.

Keay, R. W. J. (1959). An outline of Nigerian vegetation, 3rd edn. pp. 20 - 25 Federal Government Printer, Lagos.

Klinkenberg, K. and Higgins, G. M. (1968). Outline of Northern Nigeria Soils. Nig. J. of Science 2: 91 - 115.

Knavel, D. E. (1977). The influence of nitrogen on pepper transplant growth and yielding potential of plants grown with different levels of Soil Nitrogen. J. Amer. Soc. Hort. Sci. 102: 533 - 535.

Kraus, E. J. and Kraybill, H. R. (1918). Vegetation and reproduction with special reference to the Tomato. Oregon Agr. Exp. Station Bull. 149.

Kulvinder, S. and Srivastava, B. K. (1988). Effect of various levels of nitrogen and phosphorous on growth and yield of chilli (Capsicum annuum L.) Indian Journal of Horticulture 45 (3 - 3): 319 - 324.

Lal, N. and Pundrick, K. C. (1971). Effect of nitrogen phosphorous and potassium on growth and yield of chilli pepper (Capsicum frutescens L.) Punjab Agricultural Journal 11: 82 - 86.

Leopold, A. C. (1980). Plant growth and development 2nd ed. Mc Grow Hill pub cdtd. pp. 545.

Liebig, J.(1840). Die organische chemie in ihrer Anwendung auf Agriculture und Physiologie. Braunschweig.

Locascio, S. J. and Fiskell, J. G. A. (1977), Pepper production as influenced by mulch fertilizer placement under glasshouse and field conditions. Garden Banwissen shaft 43: 97 - 103.

Locascio, S. J.; Fiskell, J. G. A. and Martin, F. G. (1981). Response of bell pepper to nitrogen sources. J. Amer. Soc. Hort. Sci. 106: 625 - 632.

Lombin, G. (1981). The effects of continuous fertilization on nutrient balance and crop yeild in the Northern Nigeria savannah: A preliminary assessment. Can. J. Soil Sci. 61: 55 - 65.

Lombin, G. (1987). Soil and climatic constraints to crop production in the Nigerian savannah region. Paper presented at the 15th Annual Conference of the Soil science society of Nigeria, Kaduna, 21st - 24th Sept. 1987.

Little, T. M. and Hills, F. J. (1978). Agricultural experimentation: Design and Analysis John wiley and Sons. Inc New York. p 350.

Macy, P. (1936). The quantitative mineral nutrient requirement of plants. Plant Physiol. 11: 749 - 764.

Manchanda, A. K. and Bhopal, S. (1987). Effect of plant density and nitrogen on yield and quality of bell pepper (Capsicum annuum.L.) Indian Journal of Horticulture 44 (3-4): 250 - 252.

Maynard, D. N.; Lackman, W. H.; Check, R. M. and Vernell H. F. (1962). The influence of nitrogen levels on flowering and fruit set of peppers. Proc. Amer. Soc. Hort. Sci 81: 365 -389.

Mehlich, A. (1978). New extractant for soil test evaluation of P. K. Mg, Ca, Na, Mn and Zn. Communications in soil science and plant Analysis 9 (6): 477 - 492.

Mehlich, A. (1984). Mehlich 3 soil test extractant. A modification of Mehlich 2 extractant. Communications in soil Science and Plant Analysis 15 (12): 1409 - 1416.

Mengel, R. and Kirkby, F. A. (1982). Principles of Plant nutrition 3rd ed. Inter-national potash Institute pub. pp 655.

Metwally, A. M.; El-abidin, A. Z. and Kastour, S. (1982). The effect of population density on the yield and quality of pepper. Agriculutral Research Review 60 (1): 165 - 180.

Mezhunts, B. K. (1979). The effect of spacing on photosynthesis in hydrophonically grown capsiums. Biologichesii Zhurnal Armenii 32 (1): 21 - 24.

Miller, C. W. (1961). Some effects of different levels of five nutrient elements on Bell pepper. Proc. Amer soc. for Hort. Sci. 77: 440 - 448.

Mitchell, R. L. (1970). Crop growth and Culture 1st ed. Iowa State Univ. Press pp. 349.

Mokwuenye, U (1974a). Some reflection on the problem of available phosphorus in soils of tropical Africa Samaru Conference Paper 3: 1.

Mokwuenye, U. (1974b). Fertilizer use development in the Federal Republic of Nigeria FAO/NORAD Report. pp 7 - 21.

Mokwuenye, U. (1979). Phosphorus needs of soils and crops of the savanna zone of Nigeria. Phosphorus in agriculture 76: 87 - 95.

Mokwuenye, U. (1981). Phosphorus fertilization in Nigerian Savanna soils. III. Effects of 3 phosphorus sources on available cation contents of a soil at Samaru. Samaru Journal of Agricultural Research 1 (2): 103 - 109.

Muhammed, M. (1989). The effect of nitrogen and Phosphorus fertilizers and farmyard manure on growth and yield of chilli pepper. Unpublished M.Sc. thesis, Dept. of Agronomy, A.B.U., Zaria.

Murphy, J. and Riley, J. R. (1962). A modified single solution method for the determination of p in natural waters. Annals of Chemistry 27: 31 - 36.

Nichiporovich, A. A. (1960). Photosynthesis and the theory of obtaining high crop yields. An abstract with commentery by J. N. Black and D. J. Watson. Field crop abstract 13: 169 - 175.

Nielsen, N. E. (1979). Plant factors determining the efficiency of nutrient uptake from soils. Acta Agric. Scand. 29: 81 - 84.

Ney, P. H. (1952). Studies on the fertility of Gold coast soils. III. The phosphate status of the soil. Empire Journal of Experimental Agriculture 10: 47 - 55.

Okigbo, B. N. (1975). Farming systems for the production of vegetables. Proc. in Nat. Sem. on fruits and vegetables Ibadan 48 - 62

Okigbo, B. N. and Greenland, D. J. (1976). Intercropping systems on tropical Africa. Multiple Cropping. American Society of Agronomy, modison, Wissonsin, PP. 63 - 101.

Olarewaju, J. D. (1977). Pepper fertilizer trials at Samaru unpublished research paper, I.A.R. Samaru.

Olson, R. A.; Army, T. J.; Hanwoy, J. J. and Kilmer, V. J. (1971). Fertilizer technology and use 2nd ed. Soil Science Society of America P. 217.

Olson, S. R. (1953). Soil and fertilizer phosphorus in crop nutrition, PP. 89 - 122. Academy Press, New York.

O'Sullivan, J. (1979). Response of peppers to irrigation and nitrogen. Can. J. Plant Sci. 59: 1085 - 1091.

Owonubi, J. J. and Yayock, J. Y. (1981). Climatic limitations to crop production in the savanna region of Nigeria. Paper presented at the National seminar on Green Revolution in Nigeria, A. B. U., Zaria. 21st Sept. 1981.

Ozaki, C. T. and Hamilton, M. G. (1954). Bronzing and yield of peppers as influenced by varying levels of N, P and K. Proc. Soil Sci. Soc. of Amer. 14: 185 - 189.

Ozaki, H. Y. and Key, J. R. (1965). Phosphorus and magnesium fertilization studies with pepper. Proc. Amer. Soc. of Hort. Sci. 93: 462 - 469.

Ozaki, H. and Ray, H. E. (1957). Fertilizer studies of vegetable crops grown on the sandy soils of lowest East Coast. Florida Agric. Expt. Sta. Annual Report. p.291.

Panse, V. G. and Sukhatme, P. V. (1957). Statistical Methods for Agricultural Workers. Indian Council of Agric. Res. Delhi, P. 361.

Patil, P. B. and Vijay, C. (1979). Yield performance of chilli varieties under different plant spacings. Research Bulletin of Manhattan Agric. Univ. 3 (12): 160 - 167.

Payero, J. O.; Bhangoo, M. S.and Skiner, J. J. (1990). Nitrogen fertilizer management practices to enhance seed production by Anaheim chilli pepper. Journal of the American Society for Horticultural Science 115 (2): 245 - 251.

Radford, P. J. (1967). Growth analysis formulae - Their use and Abuse Crop science 7 (3): 171 - 175.

Ramachandran, S. and Subhail, K. K. (1981). Studies on the effect of plant density and graded levels of nitrogen on yield and yield components of chilli. South Indian Hort Journal. 29 (4): 178 - 181.

Ramachander, P. R. and Prabhakar, B. S. (1989). Experimental techniques in chillies. Indian Cocoa, Areconut and spices Journal 12 (4): 116 - 117.

Rastogi, K.; Karla, B. N. and Saini, S. S. (1980). Effect of different levels of nitrogen and spacing on fruit yield of bell peppers. Punjab Horticulture Journal 20 (1/2): 85 - 90.

Reddy, R. S.; Ahmed, M. K. and Cheri, A. V (1975). Polynomial responses of CSH - 1 sorghum to varying

levels of nitrogen and phosphate, J. Res. APAU 1V (3 & 4): 81 - 83.

Rhoads, F. M. and Bloodworth, M. E. (1964). Area measurement of cotton leaves by a dry weight method. Agronomy Journal 56: 520 - 522.

Russell, E. W. (1973). Soil conditions and plant growth 10th ed. Williams clawes and son ltd. London p. 849.

Sagiv, B. and Kafkafi, U. (1976). Fertilization and manuring of sweet pepper plants in sandy soils Hassadeh 56 (10): 1726 - 1730.

Saussure, T.de (1804). Recherches chimiques surla vegetation. Paris.

Silva, R. F. and Couto, F. A. (1971). The effect of spacing and fertilizers on capsicum ripe fruit production. Hort. Abs. 42: 7863.

Singh, R. K. and Chaudhary, B. D. (1979) Biometrical Methods in Quantitative Genetic Analysis 3rd ed. Kalyani Pub. Co. New Delhi pp. 304.

Singh, R. P. (1989). Optimum plot size for yield trials on chillies. Indian Journal of Horticulture 46 (3): 404 - 406.

Sinha, M. M. (1975). Effects of closer spacing and higher nutritional doses with and without Gibberellic acid on yield and quality in chiliies (C. annuum L.) Progressive Horticulture 7 (1): 41 - 49.

Smith, P. F. (1962). Mineral Analyses of plant tissues Ann. Rev. of plant physiol 13: 81 - 108.

Snedecor, G. W. and Lochran, W. G. (1967). Statistical Methods 6th ed. Iowa State University Press, U.S.A. p.456.

Sobulo, R. A. and Osiname, O. A. (1985). Fertilizer use in the tropics - Nigeria Experience. Proc. International Soc. of Soil science 21st - 26th July, 1985, Ibadan Nigeria pp. 193 - 203.

Stambera, J. and Petrikova, V. (1976). Effects of nutrition on the growth characteristics of capsicums. Hort.Abs. 48: 5606.

Steel, R. G. and Torrie, J. W. (1984). Principles and Procedure of Statistic: A Biometrical Approach 2nd ed. MacGrow-Hill Inter. Book auckland p. 633.

Strelec, V. and Duda, M. (1981). Relationships between economic and biological yields from the aspect of plant density. Horticultural Abstract 53 (7): 459 - 460.

Stroelilein, J . L. (1979). Effect of nitrogen and phosphorus on yields and tissue analysis of chilli peppers. Fertilizer Abstact 12 (6): 1325.

Tomlinson, P. R. (1969). Soils of the Northern Nigeria, Samaru Misc. paper No. 11, I.A.R., A.B.U., p. 12.

Topoleski, T. (1967) Home vegetable garden New York State College of Agric. Cornell. Extension Bulletin No. 1191.

Troug, E. (1930). The determination of readily available phosphorus of soils. J. Amer. Soc. Agron. 22: 879.

Udo, E. J. and Ogunwale, J. A. (1977). Phosphorus in selected Nigerian soils. J. Soil Sci. Soc. Amer. 41: 1141 - 6.

Ulrich, A. (1952). Physiological bases for assessing nutritional requirements of plants. Ann. Rev. plant. Physiol. 3: 207 - 228.

USDA (1960). Soil classification, a comprehensive System, 7th approximation. United States department of Agriculture, Washington.

Usman, I. S. (1990). Effect of Age of seedlings and nitrogen nutrition on the gorwth and yield of chilli pepper (C frutescens) Unpublished M.Sc. Thesis. Agronomy department, A.B.U., p. 91.

Uzo, J. O. (1971). Effect of nitrogen, phosphorus and potassium on yield of tomato. Tropical Hort. Res. 11: 65 - 75.

Uzo, J. O. (1976). Response of Tomato to application of phosphorus in an acid ferrallitic sandy loam soil under humid tropical climate. Hort. Res. 15: 53 - 63.

Watson, D. J. (1947). Comparative Physiological studies on the growth of field crops. I. Variation in NAR and leaf area between species and varieties and within and between years. Ann. Bot. N.S. 2: 41 - 76.

Watson, D. J. (1952). The Physiological basis of variation in yield. Advances in Agronomy 4: 101 -104.

Watson, D. J. (1958). The dependence of net assimilation rate on leaf area index. Annal of Botany 22: 37 - 54.

Wien, H. A.; Tripp, K. E. Armenta, H. R. and Turner, A. R. (1989). Abscission of Reproductive structures in pepper: Causes, mechanisms and control AVRDC Ed. Proc. of the Inter. Symp. on Integrated management practices p. 150 - 164.

Wild, A. (1971). The potassium status of soils in the savanna zone of Nigeria. Expl. Agric. 7: 257 - 270.

Wiley, R. W. (1979). Intercropping. Its importance and research needs Competition and yield advantage. Field Crop abstract 33: 1 - 10.

Williams, C. N. and Joseph, K. T. (1976). Climate, Soil and Crop Production in the Tropics. Oxford Univ. Press. London, p. 177.

Wright, S. (1960). Path-coefficients and Regressions: Alternative or complementary Concepts Biometrics 16: 189 - 202.

Wolf, B. (1982). An improved universal extracting solution and it's use for diagnosing soil fertility Communications in Soil Science and Plant analysis 13 (2): 1005 - 1033.

Yamashita, S. and Goto, Y. (1963). Effect of mineral nutrients on the flower buds differentition of crops (part 4). Influence of phosphorus on the first flower cluster differentiation of tomato plants. Soil Sci. plant Nutri. 9: 202.

Yanateva, E. A. and Elogin, V. D. (1977). The effect of spacing on Capsicum photosynthesis, Skl AKD. Timiryozva 236,101 - 104. cited in Hort Abs. 44: 1234, 1978.

Yosef, H. and Yoyeh, Z. (1988). Review of hot pepper research, short and long - term strategies. Paper presented at the 19th National Crop Improvement Conference Addis Ababa, 1 - 4 April, 1987.

Yunana, R. (1982). The effect of mixed cropping and seedling age on the performance of pepper (Capsicum spp.) Unpublished M.Sc. Thesis, Agronomy Dept., A.B.U., p. 158.

Zayeed, F. A.; El-Zawil, A. I. and Nofal, T. S. (1989). Studies on growth, productivity and some physiological aspects of hot peppers (Capsicum annuum L.) Journal of Agric. Science 10 (1): 191 - 198.

APPENDIX I. Samaru Meteorological Observations in 1991.

Month	Rainfall		Relative Humidity (%)		Air Temperature (^{0}C)		SUNSHINE
	mm)	Days	Am	Pm	Min	Max	(Hrs)
Jan.	0.0	0	21.5	17.4	14.3	29.6	8.4
Feb.	0.0	0	20.4	22.9	17.5	35.4	8.6
March	44.7	2	27.4	17.7	20.6	35.2	7.6
April	47.8	6	54.3	33.4	22.8	35.5	8.2
May	243.0	20	76.8	60.5	21.3	30.8	6.4
June	87.0	11	78.4	64.3	20.7	30.1	6.9
July	189.6	16	80.3	69.9	20.0	28.1	9.7
Aug.	329.0	18	84.0	72.5	19.7	27.9	9.0
Sept.	51.2	10	72.8	58.8	20.0	31.3	8.1
Oct.	28.7	2	66.0	40.0	18.3	32.0	8.5
Nov.	0.0	0	20.8	17.3	12.9	31.6	8.9
Dec.	0.0	0	21.1	16.3	12.6	28.6	7.7
Total	1021.0	85					
Mean			52.0	40.9	18.4	31.3	7.5

Source: Meteorological data at Institute for Agricultural Research, Samaru, Zaria.

APPENDIX 2. Samaru Meteorological Observations in 1992.

Month	Rainfall		Relative Humidity (%)		Air Temperature (°C)		SUNSHINE
	(mm)	Days	Am	Pm	Min	Max	(Hrs)
Jan.	0.0	0	21.5	14.6	12.3	26.7	9.3
Feb.	0.0	0	12.6	9.1	15.0	30.0	7.9
March	0.0	0	23.4	16.6	19.5	35.0	5.9
April	32.3	1	41.3	29.9	22.4	35.4	7.4
May	73.1	9	66.4	49.7	22.1	33.0	7.4
June	112.4	7	71.3	57.9	19.7	29.6	6.2
July	243.6	16	82.6	68.1	19.8	28.4	6.2
Aug.	287.3	16	83.0	74.8	20.2	29.5	4.9
Sept.	229.7	11	78.6	65.1	20.2	29.5	4.6
Oct.	39.9	3	61.1	35.2	17.7	31.5	8.9
Nov.	2.6	1	32.4	35.0	15.1	29.7	6.9
Dec.	0.0	0	25.1	24.6	12.3	29.6	7.9
Total	1020.9						
Mean			49.94	40.05	18.33	30.66	6.63

Source: Meteorological data at Institute for Agricultural Research, Samaru, Zaria.

APPENDIX 3. Samaru Meteorological Observations in 1993.

Month	Rainfall (mm)	Days	Relative Humidity (%) Am	Pm	Air Temperature (^{0}C) Min	Max	SUNSHINE (Hrs)
Jan.	0.0	0	23.6	19.2	11.6	26.3	4.0
Feb.	0.0	0	19.5	23.3	14.6	31.8	N.A
March	0.0	0	31.5	29.7	18.2	34.4	N.A
April	8.3	4	42.7	33.8	23.5	36.5	N.A
May	113.6	12	62.9	46.8	22.0	37.8	8.2
June	155.8	9	72.7	51.8	20.9	31.7	7.6
July	269.0	12	78.4	56.7	20.2	29.5	6.6
Aug.	300.8	16	81.8	62.1	19.5	28.4	5.0
Sept.	181.8	12	76.7	58.2	19.3	30.2	7.0
Oct.	32.4	3	63.1	54.0	18.7	34.1	8.4
Nov.	0.0	0	N.A	N.A	14.1	33.6	8.6
Dec.	0.0	0	31.3	25.5	14.1	29.1	6.2
Total	1061.7	68					
Mean			48.7	38.4	18.1	32.0	5.1

Source: Meteorological data at Institute for Agricultural Research, Samaru, Zaria.

N.A. Not available.

Appendix 4. Physico-chemical properties of the soil at the site of the experiments, Samaru.

Soil property	Soil Property		
	1991	1992	1993
Particle size distribution (%)			
Clay	14	10	12
Silt	46	42	44
Sand	40	48	44
Textural Class	Loam	Loam	Loam
PH 1:2.5			
Water	5.40	5.50	6.00
0.01 $CaCl_2$	4.20	4.40	5.10
Organic Carbon (%)	0.60	0.35	0.30
Available phosphorous (ppm)	8.064	8.80	6.35
Total Nitrogen (%)	0.056	0.04	0.04
Exchangeable bases			
(meq/100g soil)			
Ca	3.00	1.20	1.19
Mg	0.77	0.43	0.41
K	0.16	0.30	0.26
Na	0.10	0.11	0.10
C.E.C	5.10	5.80	6.10
Exchangeable acidity (meq/100g soil)			
H + Al	0.20	0.20	0.18

BIOGRAPHY

Name: Lamido ALIYU

Date of birth: 4th February, 1965

Business Address: Department of Agronomy,
A.B.U. Zaria, P.M.B. 1044 Zaria.

Home Address: No. 657 K/Nasarawa, Kano City, Kano State.

Previous Qualifications: B.Sc (Agric.); M.Sc (Agronomy).

Institutions attended	Period	Certificate
Kwalli Primary School	1970-1977	School leaving Cert.
Govt. Sec. School Gwarzo	1978-1982	G.C.E.
S.B.S., A.B.U, Zaria	1982-1983	I.J.M.B.
Ahmadu Bello University Zaria.	1983-1987	B.Sc. (Agriculture)
Ahmadu Bello University Zaria	1988-1990	M.Sc (Agronomy)

Posts held since the award of first Degree

Organisation	Period	Position
N.Y.S.C	1987-1988	Teacher
Ministry of Education Kano State	Aug.-Nov. 1988	Education Officer
Ahmadu Bello University Zaria	1988-1991	Assistant Lecturer
Ahmadu Bello University Zaria	1991 to date	Lecturer II

Year of Admission into Post-graduate School - 1990

Admission Number:Ph.D/AGRIC/1330/1990-91