

**STUDY ON THE INFLUENCE OF PLANT POPULATION AND
SPLIT APPLICATION OF NITROGEN ON SUNFLOWER
UNDER RAINFED CONDITIONS**

**Thesis submitted in part fulfilment of the requirements for the Degree of
Master of Science (Agriculture) in Agronomy to the Tamil Nadu Agricultural
University, Coimbatore - 641 003.**

By

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1999

CERTIFICATE

This is to certify that the thesis entitled "STUDY ON THE INFLUENCE OF PLANT POPULATION AND SPLIT APPLICATION OF NITROGEN ON SUNFLOWER UNDER RAINFED CONDITIONS" submitted in part fulfilment of the requirements for the degree of Master of Science (Agriculture) in Agronomy to the Tamil Nadu Agricultural University, Coimbatore is a record of bonafide research work carried out by **Mr. M. Vijayakumar** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.



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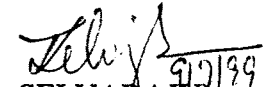
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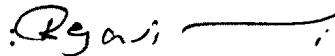


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Date : 9.7.1999

Acknowledgement

ACKNOWLEDGEMENT

I express my external indebted towards **THE ALMIGHTY** for His grace, guidance, lustre and blessings showered on me incessantly on all parts of my life including putting forth this research piece.

My sincere and deep sense of gratitude belongs to **Dr.P. Subbian**, Associate Professor of Agronomy, Agricultural College and Research Institute, Coimbatore for his expert guidance and chairmanship and for his efforts and constant encouragement given to achieve this goal.

I am highly grateful to the members of the advisory committee, **Dr.T.N.Balasubramanian**, Professor and Head, Department of Agricultural Meteorology, **Dr.C.Udayasoorian**, Associate Professor of Soil Science and Agricultural Chemistry and **Dr.R.Selvaraju**, Assistant Professor of Agronomy, Agricultural College and Research Institute, Coimbatore for their valuable suggestions and enlightments given in bringing out this thesis.

My special thanks are extended to **Dr.R.Selvaraju** for his limitless help during the course of study.

I wish to express my sincere thanks to **Dr. J. Krishnarajan**, Professor and Head, Department of Agronomy, **Dr.A.Balasubramanian**, **Dr.C.Chinnusamy**, **Dr.S.Panneerselvam**, **Dr.M.Balusamy**, **Dr.A.Velayutham** and **Dr.K.K.Suresh** for their kind advice in putting forth this thesis work.

My sincere thanks to Karthi, Alagu, Push, Saba, Dinesh, Mari, Satheesh, Seenu, Suhas, Boss, Murali and Lenin also all other friends especially Amudha, Senthilvel, Mehari, Harish, Phap, Mohana and Selvi.

I feel delighted to recall the help of senior friends especially Sivamurugan, Satheesh, Raja, Sakthi, Logu and Velu.

On a personal note, I wish to place on record my loving thanks to my Father, Marappa gounder, Mother, Rajammal, Brother, M.Selvaraju, Aunt, Sarasu and all my wishers for their everlasting encouragement and whole heartfelt blessings.

I extend my thanks to Ganapathy Computers for the type setting and neat execution of this work.

Date:


M.VIJAYAKUMAR

Abstract

ABSTRACT

STUDY ON THE INFLUENCE OF PLANT POPULATION AND SPLIT APPLICATION OF NITROGEN ON SUNFLOWER UNDER RAINFED CONDITIONS

By

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**DEGREE : MASTER OF SCIENCE (AGRICULTURE)
IN AGRONOMY**

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✓ Field experiments were conducted during North east monsoon seasons of 1997 and 1998, at Tamil Nadu Agricultural University Farm, Coimbatore to study the effect of plant population and split application of nitrogen on sunflower under rainfed conditions. The experiments were laid out in split plot design with three replications. The main plot treatments consisted of three plant population levels viz., 30x37.5 cm (88,888 plants ha⁻¹), 30 x 30 cm (1,11,111 plants ha⁻¹) and 30 x 25 cm (1,33,333 plants ha⁻¹). The sub plots comprised of six split levels of nitrogen viz. N₁ (full basal application of 40 kg N ha⁻¹), N₂ (½ basal + ½ on 4th week after sowing with rain), N₃ (½ basal + ½ on 6th week after sowing with rain), N₄ (½ basal + ¼ on 4th week after sowing + ¼ on 6th week after sowing with rain),

N_5 ($\frac{1}{3}$ basal + $\frac{1}{3}$ on 4th week after sowing + $\frac{1}{3}$ on 6th week after sowing with rain) and N_6 ($\frac{1}{4}$ basal + $\frac{1}{2}$ on 4th week after sowing + $\frac{1}{4}$ on 6th week after sowing with rain).

The quantity of rainfall received during the cropping period of 1997 and 1998 were 598 mm and 571.2 mm distributed over 43 and 20 rainy days respectively.

The study revealed that the plant height, leaf area index and dry matter production were higher at closer spacing of 30x25 cm (1,33,333 plants ha⁻¹) than at wider spacing of 30 x 37.5 cm (88,888 plants ha⁻¹). At higher population level (33,333 plants ha⁻¹) the stem girth was comparatively lesser than at lower population level (88,888 plants ha⁻¹).

The higher population level registered increased CGR and NAR values in both the years, whereas it had only a marginal effect on RGR irrespective of years of study.

In both the years, the treatment with lower plant population (88,888 plants ha⁻¹) recorded the maximum values of yield attributes viz. head diameter, total number of seeds head⁻¹, filling percentage and 100 seed weight. In 1997 higher plant population at 30 x 25 cm plant spacing recorded highest seed yield, stalk yield and oil yield. However in 1998, the lower plant population of 88,888 plants ha⁻¹ at 30 x 37.5 cm spacing recorded more seed and oil yield.

The oil content was marginally higher under closer spacing (30 x 25 cm) than under wider spacing (30 x 37.5). The variation in protein content under different population levels was not significant in 1997. But in 1998, it was significantly higher at lower plant population level.

The uptake of N, P and K was maximum under closer plant population levels in both the years.

Gross returns, net returns, B:C ratio and per day return were maximum under higher plant population level of 1,33,333 plants ha⁻¹ during 1997 whereas in 1998, the same were higher at lower plant densities of 88,888 plants ha⁻¹.

Split application of N at different growth stages produced higher growth parameters in both the years compared to full basal application. In general, split application of N was found to be better in increasing the growth and yield of sunflower when compared to full basal application. In 1997, split application of N ($\frac{1}{2}$ basal + $\frac{1}{4}$ on 4th week after sowing + $\frac{1}{4}$ at 6th week after sowing) recorded maximum plant height, stem girth and dry matter production. It also recorded higher NAR, head diameter, total number of seeds head⁻¹, filling percentage and 100 seed weight. Seed yield, oil yield, protein content and NPK uptake were also higher under this treatment.

In 1998, application of N in two splits ($\frac{1}{2}$ basal + $\frac{1}{2}$ on 4th weeks after sowing with rain) resulted in higher plant height, stem girth, LAI, DMP and NAR. The head diameter, total number of seed head⁻¹, filling percentage, 100 seed weight, seed and oil yield and NPK uptake were also higher under this treatment.

With regard to economics, the gross return, net return, B:C ratio and per day return were higher with application of N at 3 splits ($\frac{1}{2}$ basal + $\frac{1}{4}$ 4th week after sowing + $\frac{1}{4}$ at 6th week after sowing with rain) during 1997 and at 2 splits ($\frac{1}{2}$ basal + $\frac{1}{2}$ at 4th week after sowing with rain) during 1998.

Contents

Sl. No.	Title	Page No.
1.	Introduction	1 - 3
2.	Review of Literature	4 - 20
3.	Materials and Methods	21 - 37
4.	Experimental Results	38 - 74
5.	Discussion	75 - 94
6.	Summary	95 - 99
	References	-
	Appendix	-

LIST OF TABLES

Table No.	Titles	Page No.
1	Soil characteristics of the experimental site	26
2	Varietal characters of sunflower	27
3	Effect of plant population and nitrogen split application on plant height (cm) of sunflower	39
4	Effect of plant population and nitrogen split application on stem girth (cm) of sunflower	41
5	Effect of plant population and split application of nitrogen on dry matter production (kg ha^{-1}) at 30 DAS	43
6	Effect of plant population and split application of nitrogen on dry matter production (kg ha^{-1}) at 50 DAS	44
7	Effect of plant population and split application of nitrogen on dry matter production (kg ha^{-1}) at harvest	45
8	Effect of plant population and N split application on leaf area index of sunflower	47
9	Effect of plant population and split application of N on CGR ($\text{g m}^{-2} \text{ day}^{-1}$)	49
10	Effect of plant population and split application of N on RGR ($\text{mg gm}^{-1} \text{ day}^{-1}$)	51
11	Effect of plant population and split application of N on NAR ($\text{cm}^2 \text{ g}^{-1} \text{ day}^{-1}$)	53
12	Effect of plant population and nitrogen split application on number of days to 50 per cent flowering of sunflower	54

Table No.	Titles	Page No.
13	Effect of plant population and nitrogen split application on yield attributes of sunflower	56
14	Effect of plant population and nitrogen split application on yield attributes of sunflower	58
15	Effect of plant population and split application of nitrogen on seed yield (kg ha^{-1}) of sunflower	60
16	Effect of plant population and split application of nitrogen on stalk yield (kg ha^{-1}) of sunflower	61
17	Effect of plant population and nitrogen split application on crude protein (%), oil content (%) and oil yield (kg ha^{-1}) of sunflower	63
18	Effect of plant population and N split application on nitrogen uptake (kg ha^{-1}) of sunflower	65
19	Effect of plant population and N split application on phosphorus uptake (kg ha^{-1}) of sunflower	67
20	Effect of plant population and N split application on potassium uptake (kg ha^{-1}) of sunflower	69
21	Effect of plant population and N split application on post harvest soil available nutrient (kg ha^{-1})	71
22	Economics - NEM 1997	72
23	Economics - NEM 1998	73

LIST OF FIGURES

Figure Number	Title	Page Number
1	Weather data - NEM 1997	23
2	Weather data - NEM 1998	24
3	Field lay-out plan - NEM 1997	28
4	Field lay-out plan - NEM 1998	29
5	Effect of plant population and split application of nitrogen on dry matter production (kg ha^{-1}) - NEM 1997	76
6	Effect of plant population and split application of nitrogen on dry matter production (kg ha^{-1}) - NEM 1998	77
7	Effect of plant population and N split application on leaf area index of sunflower - NEM 1997	82
8	Effect of plant population and N split application on leaf area index of sunflower - NEM 1998	83
9	Effect of plant population and split application of nitrogen on seed yield (kg ha^{-1}) of sunflower	86
10	Effect of plant population and N split application on nitrogen uptake (kg ha^{-1}) of sunflower - NEM 1997	89
11	Effect of plant population and N split application on nitrogen uptake (kg ha^{-1}) of sunflower - NEM 1998	90
12	Economics and monetary returns of treatments in sunflower - NEM 1997	92
13	Economics and monetary returns of treatments in sunflower - NEM 1998	93

LIST OF PLATES

Plate Number	Title
1	General view of the experimental field
2	Recommended plant population (30 x 30 cm) with full basal application - NEM 1997
3	120% of recommended plant population (30 x 25 cm) with nitrogen application as three splits (N ₄) - NEM 1997
4	80% of recommended plant population (30 x 37.5 cm) with two N splits (N ₂) Vs 120% of recommended plant population (30 x 25 cm) with three N splits (N ₄) - NEM 1998

LIST OF APPENDICES

**Appendix
Number**

Title

- | | |
|---|-------------------------------------|
| 1 | Weather data - NEM 1997 |
| 2 | Weather data - NEM 1998 |
| 3 | Soil available moisture (mm) - 1997 |
| 4 | Soil available mositure (mm) - 1998 |

Introduction

CHAPTER I

INTRODUCTION

Sunflower (*Helianthus annuus*) is an important oil seed crop which ranks third in the world next to soybean and groundnut in the edible oil production. It is cultivated extensively in countries like U.S.S.R., Bulgaria, Rumania, Canada and South America, over an area of 14.8 million hectares with a production of 21.3 million tonnes (FAO, 1989). In India, sunflower occupies an area of 1.28 million hectare with a production of 1.16 million tonnes (Hegde and Kiresur, 1999). Although the area under sunflower is increasing steadily in India, the per hectare yield remains around 700 kg/ha⁻¹ only (Jagadish *et al.*, 1995). In Tamil Nadu, the area and production of sunflower showed wide fluctuations since its introduction in mid seventies. The crop is now being cultivated in 26,450 ha with a total production of 14,835 tonnes (TNAU, 1998).

The projected requirement of oils and fats by 2000 AD in India is 6.6 million tonnes as against the present production of 2.9 million tonnes. The per capita availability of edible oil is only 6.46 kg (Acharya, 1989) which is far below the nutritional norm of 14 kg per annum. Sunflower with its photo-insensitivity and adaptability to wider range of environment has greater potential in increasing the total oil seeds production in India. Besides its oil quality, sunflower seed has 30 per cent protein which is more useful as good livestock feed.

Planting pattern has been observed to influence the yield of many crops. Sunflower expresses its full genetic potential when it is grown in an ideal ecological environment with optimum soil fertility and plant population levels. It is imperative to adopt optimum plant population for better utilization of all the resources more efficiently. Studies conducted in different parts of the country

indicated that plant population ranging between 0.6 and 1.0 lakh plants ha⁻¹ is optimum for most of the sunflower varieties (Jensma, 1972).

Under dryland situation, maintainance of plant population plays a major role in increasing the sunflower yield especially in high rainfall years. The productivity of sunflower can also be increased with judicious use of inputs under higher plant population levels. It is also important to reduce the yield loss against abiotic stress especially with inadequate soil moisture by proper manipulation of plant population. Under low rainfall situations, maintaining lesser plant population than the recommended level would be beneficial for better yields.

Among the plant nutrients, nitrogen plays an important role in deciding growth and yield of sunflower. Nitrogen is the most common element influencing the sunflower yield (Ashnour *et al.*, 1985 and Halder *et al.*, 1998). Sunflower can utilize either nitrate or ammoniacal N but grows better with nitrate (Steer and Hocking, 1984). With the advent of improved sunflower varieties and pressing demand to increase the productivity, split application of nitrogen at critical stages is necessary for proper growth and yield.

As moisture is the most limiting factor in drylands, split application of N provides the opportunity to make seasonal decision to optimise the N dose based on rainfall occurrence. This indicates that fertilizer requirements and time of application may not be same under highly variable rainfall situations. Hence it is necessary to optimise the time of split application of N with respect to production level for a particular rainfall pattern.

As there is not adequate research work on plant population and nitrogen split applications on sunflower crop under rainfed conditions, the present investigation was planned and conducted with the following objectives.

1. To find out the influence of plant population levels on the growth and yield of sunflower under dryland vertisols
2. To study the effect of split application of nitrogen on the growth, yield and nutrient uptake of sunflower
3. To optimise the plant population and split application of nitrogen for rainfed sunflower based on economic analysis.

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Plant population and fertilization are the two major factors which influence the seed yield of sunflower considerably (Hegde and Havanagj, 1987; Khalifa, 1981). Due to escalating cost of inorganic fertilizers especially nitrogen, split application is much useful in increasing the N use efficiency. Maintaining plant population at optimum level especially under rainfed situations is also important for maximising the yields. Research works carried out on plant population and nitrogen split application in increasing the growth and productivity of sunflower are reviewed in this chapter.

2.1. Effect of plant population on growth components

2.1.1. Plant height

Singhi and Pacheria (1981) studied the effect of plant density on sunflower and reported that higher plant population (1,48,148 plants ha⁻¹) registered maximum plant height of 132cm compared to 125cm under lower plant population (74,074 plants ha⁻¹) levels. Miller and Roath (1982) obtained 1.8, 4.4 and 8.2 per cent less plant height at 37, 500, 25,000 and 12,500 plants ha⁻¹ respectively compared to 55,555 plants ha⁻¹. Increased plant height with increase in plant population was also observed by several researchers (Holt and Campbell, 1984; Gubbels and Dedio, 1990). Sarmah *et al.* (1992) found that during the initial vegetative phase (upto 30 days) plant population had less significant influence on plant height than later stages. The plant height of sunflower was increased due to severe competition for light and space which favoured identical elongation of shoot (Rajput *et al.*, 1994; Esechie *et al.*, 1996; Goksoy *et al.*, 1998).

2.1.2. Stem girth

Reduction of stem girth of sunflower by 14 per cent was observed when the plant population was increased from 74, 074 to 1,48,148 plants ha⁻¹ (Singhi and Pacheria, 1981). Hegde and Havanagi (1987) noticed significantly higher stem diameter (5.33cm) at 27, 777 plant ha⁻¹ over 2,22,222 plants ha⁻¹. Generally stem diameter decreased with increasing plant population both at flowering and at harvest (Gajendra Giri, 1996; Zaffaroni and Schneiter, 1991).

2.1.3. Leaf area

Higher plant density of sunflower in general was found to reduce the leaf area (Narwal and Malik, 1985; EL-Mohandas, 1989). Khargakharate *et al.* (1991) obtained higher leaf area at 60cm inter row spacing and further noticed that the leaf area was highest at 22.5 cm than at 17.5 cm and 15cm intra row spacings. Sarmah *et al.* (1992) observed that reducing the plant density from 1,11,111 plants ha⁻¹ to 49,382 plants ha⁻¹ significantly increased the leaf area of sunflower.

2.1.4. Leaf area index

Savaner (1975) reported that decreasing spacing from 50 x 50 cm to 40 x 40 cm and 30 x 30 cm increased leaf area index and photosynthetic potential. Rao and Reddy (1985) recorded significant increase in leaf area index from 2.89 to 4.54 at 60 DAS with increase in plant population from 55, 555 to 1,11,111 plants ha⁻¹. Similarly Smith *et al.* (1981) observed 0.24 per cent increase in leaf area index for increase in one plant m⁻² from 4 to 12 plants m⁻². According to Hegde and Havanagi (1987) the leaf area index of sunflower were 0.78 and 3.93 at 27,777 and 2,22,222 plants ha⁻¹ respectively.

2.1.5. Drymatter production

Total drymatter production plant^{-1} decreased with increase in plant population at all the growth stages of sunflower (Hegde and Havanagi, 1987; Majid and Schneiter, 1988). However, total drymatter yield increased positively with higher plant density (Rebanco *et al.*, 1989). Significant increase in dry matter production and its distribution in different plant parts of sunflower with increase in plant density was reported by EL-Mohandas (1989) and Zaffaroni and Schneiter (1991). Lower dry matter accumulation plant^{-1} at higher plant densities was mainly due to the inter plant competition for light, moisture, nutrient and space (Sarmah *et al.*, 1992; Esechie *et al.*, 1996).

2.1.6. Crop phenology

Smith *et al.* (1981) noticed delay in days to flowering with increase in plant population from 4 to 12 plant m^{-2} . Higher plant density with 1,60,000 plants ha^{-1} advanced maturity of the crop by two weeks over 40,000 plants ha^{-1} (Baylis and Dick, 1983). According to Majid and Schneiter (1988) the days to anthesis increased with increase in plant population while days to maturity decreased with increased plant population (Holt and Campbell, 1984).

2.2. Plant population on yield attributes

2.2.1. Head diameter

Sarmah *et al.* (1994) revealed that lower plant density of 49,382 plant ha^{-1} gave significantly larger and heavier heads than higher plant density with 1,11,111 plants ha^{-1} . Rajput *et al.* (1994) noticed significant increase in head diameter by adopting a wider spacing of 50x20cm than closer spacing. Gajendra Giri (1996) obtained higher head diameter with lower plant density. Goksoy *et al.* (1998)

recorded, reduced head diameter with increase in plant population from 30,000 to 95,000 plant ha⁻¹. The inverse relationship of head diameter and plant density of sunflower was also reported by several researchers (Karami, 1980; Miller and Roath, 1982; Kameshwara Rao and Gangasaran, 1991; Zaffaroni and Schneiter, 1991).

2.2.2. Total number of seeds head⁻¹

Reduction in total number of seeds head⁻¹ with increase in plant population of sunflower was reported by Narwal and Malik (1985). Hegde and Havanagi (1987) reported significant reduction in number of seeds head⁻¹ from 803 to 222 with increase in plant population from 27,777 to 2,22,222 plant ha⁻¹. The number of seeds head⁻¹ were 403 and 376 at a population of 1.11 and 1.65 lakhs plants ha⁻¹ respectively (Kameshwara Rao and Gangasaran, 1991).

2.2.3. Number of filled seeds head⁻¹

There was significant increase in per cent seed filling from 82 to 88 with decrease in plant population from 2,22,222 plants to 27,777 plants ha⁻¹ (Hegde and Havanagi, 1987). Percentage of filled seeds was reduced from 65 to 59 when the spacing was reduced from 45 x 30cm to 30x15cm (Kene *et al.*, 1992). Subarad and Sheelavantar (1997) reported that the number of filled seeds were higher (619) when grown at 0.83 lakh plants ha⁻¹. On the contrary, Narwal and Malik (1985) did not notice any differences in per cent filled seeds due to different plant population levels.

2.2.4. Number of unfilled seeds head⁻¹

Per cent of unfilled seed was increased from 3.6 to 12.8 with increase in plant population from 17,700 to 1,11,111 plants ha⁻¹ (Umrani and Bhoi, 1985).

Similarly more number of unfilled seeds head⁻¹ with increase in plant population was reported by Sarmah *et al.* (1994) and Goksoy *et al.* (1998).

2.2.5. Test weight

Plant population was found to affect the seed size in sunflower resulting in variation in test weight. Sunflower crop adjusts to low populations with increased seed weight. Majid and Schneiter (1987) noticed significant reduction in test weight (4.8 to 3.6g) with increase in plant population from 32,123 to 1,01,311 plants ha⁻¹. Higher test weight of 5.4 g was recorded at lower plant population of 27,777 plants ha⁻¹ (Hegde and Havanagi, 1987).

The single achene weight was found to decrease from 61.7 to 50.5 mg with increase in plant density from 55,000 to 1,48,000 ha⁻¹ (Gubbels and Dedio, 1990). Kameswara Rao and Gangasaran (1991) obtained higher test weight of 3.9g at lower plant population (1,11,111 plants ha⁻¹) compared to 3.8 g at higher plant density (1,67,000 plants ha⁻¹).

Plant spacing was found to affect the 100 seed weight slightly when grown at higher plant population levels (Bhoite and Nimbalkar, 1995). Krishnakumar and Vireshwar Singh (1995) observed that the 100 seed weight was significantly higher at a spacing of 60 x 20cm compared to 40 x 30cm. Ortegon and Diazf (1997) also recorded higher test weight at lower plant densities.

2.3. Effect of population level on seed yield and harvest index

2.3.1. Seed yield

Plant population plays a major role in influencing the seed yield of sunflower. Studies conducted at Coimbatore under black soil conditions have shown significant increase in sunflower seed yield correspondingly to increase in

plant spacing upto 45 x 30cm (TNAU, 1990). Experimental results at Punjab revealed that the seed yield of sunflower was maximum at 45cm inter row spacing when compared to 60 and 70cm inter row spacing (Singh *et al.*, 1990).

At Hisar, Sarmah *et al.* (1992) obtained a higher sunflower seed yield of 730 kg ha⁻¹ at a higher plant population of 74,074 plants ha⁻¹ followed by 690 kg ha⁻¹ at 55,555 plants ha⁻¹. Under irrigated condition at Bangalore, tall and dwarf sunflower varieties were found to give higher seed yield at 60 x 22.5 cm and 40 x 30 cm plant spacing respectively (Robinson *et al.*, 1980; Prunty, 1981). At Bahraich in Uttar Pradesh, a plant spacing of 50 x 20cm significantly increased the seed yield of sunflower compared to 40x20 and 60x20 cm spacings (Sarmah *et al.*, 1994).

The reduction in yield attributes in individual plants due to higher plant density was compensated with increase in number of plants per unit area and there by total yield was increased (Gajendra Giri, 1996). Though the yield parameters decreased significantly with increasing population from 40,000 to 1,60,000 plants ha⁻¹, the seed yield obtained at 80,000 plants ha⁻¹ was significantly higher than all the other population levels (Tenebe *et al.*, 1996). Highest seed yield obtained at higher plant densities was also reported by Esechie *et al.* (1996), Parmer and Kharwara (1992) and Tenzi *et al.* (1997).

Effect of plant population on the seed yield of sunflower also varies with growing improved cultivars. According to Majid and Schneiter (1988), the sunflower seed yield was maximum at 50,000 plants ha⁻¹ from cultivar cargil super 500 and at 75,000 plants ha⁻¹ in cultivar Docalb G-98. Sunflower cultivar odoski-128 gave higher seed yield at a plant density of 30,000 plants ha⁻¹ during the drought period and at 60,000 plants ha⁻¹ during favourable weather condition

(Liben~~co~~, 1990). With sunflower cultivar Cv EC 68414, Bindra and Kharwara (1992) obtained higher seed yield at a spacing of 45 x 30cm when compared to 60x30 and 30x30cm spacings.

Gubbels and Dedio (1990) obtained higher seed yield by growing sunflower hybrids at a plant population of 74,000 plants ha⁻¹ and the yield remained relatively constant upto 1.48 lakh plants ha⁻¹. Adopting a spacing of 45 x 20 cm, Pal *et al.* (1997) recorded the highest seed yield of 2.87 and 3.30t ha⁻¹ in sunflower variety modern and hybrid MFSH-8, respectively. However, Kameswara Rao and Gangasaran (1991) observed no significant difference in the yield of sunflower hybrids grown at 1.11 and 1.67 lakh plants ha⁻¹.

The advantage of wider row spacing in increasing the seed yield of sunflower was reported by several researchers (Vijayalakshmi *et al.*, 1975; Dhoble *et al.*, 1988; Krishnakumar and Vireshwar Singh, 1995; Subarad and Sheelavantar, 1997). However, Karami (1997) found that closer spacing was advantageous in producing higher seed yield of sunflower when compared to wider spacing under no moisture stress condition. The favourable effect of closer spacing in increasing the seed yield of sunflower was also reported by Goksoy *et al.* (1998). However Halder *et al.* (1998) noticed significant reduction in seed yield of sunflower due to closer spacing.

The optimum plant population ha⁻¹ to get higher yield in sunflower was found to be 55,555 in Iran (Karami, 1980), 62,000 in USA (Mathers and Stewart, 1982), 45,000 to 65,000 in Bulgaria (Klochkov, 1985), 80,000 in Chile (Mora and Tatter, 1987) and 60,000 to 65,000 in Chechoslovakia (Kovacik and Skaloud, 1988). Similarly at Bangalore, India the optimum plant spacing for tall and dwarf

(morden) sunflower varieties were 74,074 and 83,333 plants ha⁻¹ respectively (Sindagi and Virupakshappa, 1990).

Shaik and Rama Rao (1981) did not observe significant differences in seed yield of sunflower due to varied plant populations on sandy loam soils of Hyderabad. Experimental results stating no difference in seed yield of sunflower with varied plant population levels was also reported by Kameswara Rao and Gangasaran (1991) and Malik *et al.* (1992).

Subarad and Sheelavantar (1997) recorded significantly higher seed yield of (15.83 q ha⁻¹) at 0.83 lakh plants ha⁻¹ which is 13 per cent higher than grain yield produced at a population of 1.11 lakh plants ha⁻¹. Closer spacing was found to be advantageous in producing higher seed yield compared to wider spacing under no moisture stress conditions (Karami, 1997).

However Shaik and Rama Rao (1981) did not observe significant differences in seed yield due to varied plant population on sandy loam soils at Hyderabad. Similarly seed yield of sunflower was not influenced by varied plant population levels (Holt and Cambell, 1984; Kameswara Rao and Gangasaran, 1991; Malik *et al.*, 1992).

2.3.2. Harvest index

Majid and Schneiter (1988) found that harvest index of sunflower differed slightly with plant density. The harvest index were 34.4 and 39.4 per cent at a population of 1,01,311 and 32,123 plant ha⁻¹ respectively. Similarly, higher harvest index (35.2%) was registered at lower plant population of 35,000 plants ha⁻¹ compared to higher population of 65000 plants ha⁻¹ (Zaffaroni and Schneiter, 1991).

2.4. Effect of plant population on quality parameters

2.4.1. Protein content

The protein content of sunflower seed was maximum (23.7%) at 55,555 plants ha⁻¹ and minimum (22.9%) at 1,11,111 plants ha⁻¹ (Srinivas and Patil, 1977). Rajasekhar *et al.* (1997) observed that application of 100 per cent of recommended dose of fertilizer with 50 per cent of population produced highest total protein yield of 672 kg ha⁻¹.

2.4.2. Oil content

Klochkov (1985) reported that increase in plant density of sunflower from 35,000 to 60,000 plant ha⁻¹ increased the average oil content in seeds. Significant increase in oil content (43.7 to 46.5%) was noticed with increasing levels of plant population from 32,123 to 1,01,311 plants ha⁻¹ (Majid and Schneiter, 1987). Increase in oil content with increase in plant density was also reported by Gubbels and Dedio (1990) and Harmati (1990). Karami (1997) observed that wider spacing considerably reduced the oil content of sunflower. However, several other workers opined that plant population had no significant effect on oil content of sunflower seeds (Narwal and Malik 1985; Kameswara Rao and Gangasaran, 1991).

2.4.3. Oil yield

Higher oil yield of sunflower was noticed by maintaining a optimum plant population of 83,300 plants ha⁻¹ (Kotechi and Malarz, 1988). Khargakharate *et al.* (1991) obtained highest oil yield with 60cm inter row spacing and 22.5 intra row spacing. As plant population increased from 30,000 to 95,000 plants ha⁻¹, the oil content and oil yield were increased correspondingly under groundnut + sunflower

intercropping situation (Rajas ekhar *et al.*, 1997). However, Goksoy *et al.* (1998) found that the oil yield was reduced with increase in plant population from 30,000 to 95,000 plants ha⁻¹.

2.5. Effect of plant population on moisture use efficiency under rainfed condition

Choice of plant density for sunflower should be based on the available soil moisture content and mean precipitation (Libenco, 1990). Under moisture stress condition maintaining 50,000 plants ha⁻¹ of sunflower was found superior whereas under adequate moisture supply higher plant density produced higher seed yield (Umrani and Bhoi, 1985). Dhoble *et al.* (1988) reported that wider plant spacing of 30cm was found to be significantly advantageous for efficient moisture use over 22.5cm and 15cm plant spacing.

Subba Reddy *et al.*, (1997) revealed that moisture stress at flowering and seed formation was more harmful than during vegetative phase in influencing the growth and yield of sunflower. They also revealed that reducing plant density from 1,11,000 to 28,000 during moisture stress at vegetative and flowering stages reduced the seed yield. However, maintaining a plant population of 56,000 plant ha⁻¹ at sowing was found advantageous to get stable yield in rainfed alfisols.

Chavan *et al.* (1990) recorded highest moisture use efficiency of rainfed sunflower sown at 60x30cm spacing on 34th standard week. Ulemale *et al.* (1991) reported that rainfed sunflower grown at a spacing of 30cm between plants with 45cm and 60cm between rows gave an average seed yield of 631 and 530 kg ha⁻¹, respectively.

Kene *et al.* (1992) recorded significantly higher seed yield of sunflower with wider spacing over closer spacing due to less competition for moisture under

wider spacing at later stage. A rainy season sunflower crop grown with plant density of 50,000 plant ha⁻¹ gave 25 per cent higher seed yield than dry season crops (Ungaro *et al.*, 1996).

2.6. Effect of plant population on nutrient uptake

Kharwara and Bindra (1992) reported that the NPK uptake of sunflower was maximum at 1,11,000 plant ha⁻¹ followed by 83,000 plants ha⁻¹. Lower population of 49,382 plants ha⁻¹ significantly increased the nitrogen and phosphorus content of seeds (Sarmah *et al.*, 1995). Pradeep (1995) reported that maximum N, P and K uptake was recorded under 45x20cm spacing. This was in agreement with the findings of Girijesh and Patil (1989) and Malipatil and Patil (1990). Similarly, Nandhagopalan (1997) reported highest N, P and K uptake at a medium spacing of 45 x 30cm over 60 x 30cm. Subba Reddy and Maruthi (1997) found that thinning of plants from 1,11,000 to 28,000 plants ha⁻¹ during moisture stress at vegetative period reduced the uptake of nutrients.

2.7. Effect of nitrogen

2.7.1. Effect of split application of nitrogen on growth components

Aydin (1996) reported increased plant height due to application of N at different growth stages of sunflower. Application of 90 kg N ha⁻¹ in two equal splits (½ basal and ½ top dressing) or in two varied splits (2/3 as basal and 1/3 top dressing) recorded significantly higher LAI (Narasimha Rao and Narsa Reddy, 1982). Reddy *et al.* (1985) observed significantly higher LAI and DMP with split application of nitrogen. Nitrogen application at buttoning stage was found to promote growth of sunflower and also early translocation of photosynthates to reproductive parts (Krishna Reddy *et al.*, 1992).

Application of half doses of N at basal and the remaining half N on 60 DAS produced higher dry weight of sunflower (Bindra and Kharwara, 1994). Reddy and Gajendra (1996) observed that application of nitrogen at 60kg ha^{-1} in two splits, one at basal and the other at 25 DAS or three splits, the first at basal, the second on 25 DAS and the third at 50 DAS boosted the growth components compared to full basal application.

2.7.2. Effect of split application of nitrogen on yield components and yield

Split application of N produced bigger flower heads, more filled seeds head⁻¹ and higher 1000 seed weight (Steer and Hocking, 1984). Head diameter and filled seeds head⁻¹ were more with 60kg N ha^{-1} applied half basal and one fourth at buttoning and the remaining one fourth at flowering (Krishna Reddy *et al.*, 1992). Kharwara and Bindra (1992) reported that half the dose of N applied at the time of sowing and the remaining dose of N top dressed at 60 DAS significantly increased the yield components and seed yield of sunflower.

Basal application of half the recommended N at the time of sowing and the remaining half N in two equal splits on 20 DAS and at flower initiation had a marked effect on increasing the seed yield of sunflower (Haribabu and Chauhan, 1979). They also observed that with increased N application upto the level of 120 kg ha^{-1} , the seed yield of sunflower was maximum and the yield increase was to the extent of 196 per cent over the control.

Application of 60 kg N ha^{-1} in three equal splits gave higher sunflower seed yield which was 23.7 and 10.5 per cent higher than that of entire basal and two split application respectively (Reddy and Gajendra giri, 1997). Kumar and Reddy (1997) found that application of 90 kg N ha^{-1} in three equal splits (at sowing, buttoning and flowering) plus basal application of P and K produced highest mean

seed yield of 2.15 t ha⁻¹. Similarly different time of N application increased the yield reported by Rao *et al.*, 1976; Rao and Reddy, 1982)

2.7.3. Effect of N on nutrient uptake

Kalra and Tripathi (1980) found that sunflower crop removed 126.1, 29.8 and 82.8 kg of N, P and K ha⁻¹ respectively from soil, when applied with 120 kg N ha⁻¹. The total N uptake was higher (114.2 kg ha⁻¹) with 60 kg N ha⁻¹ than without N (Krishnagowda, 1983). Application of N significantly increased the uptake of nutrients in both seed and stalk of sunflower (Haatouk and EL Latif, 1985 and Samui *et al.*, 1987). The nitrogen uptake and soil mineral nitrogen were greater with 180 kg N ha⁻¹ compared to unfertilized control (De-Georgio *et al.*, 1990).

Application of 120 kg N ha⁻¹ registered 87.1, 108.9 and 85.2 per cent increase in N, P and K uptake respectively by seed, compared to control (Sunil Kumar *et al.*, 1991). Nitrogen application at higher doses increased N and P content and concentration of all plant components at early growth stages only (Loubser and Human, 1993). Monoharan *et al.* (1991) reported that the uptake of N and P in sunflower increased with increasing levels of N. Sarmah *et al.* (1995) found that N uptake of sunflower was maximum with 80kg N ha⁻¹. Mishra *et al.* (1995) inferred from a study in sandy loam soils at Bhuvaneswar that application of N upto 60kg N ha⁻¹ increased the uptake of N, P and K by sunflower.

2.8. Interaction effect of nitrogen and plant population

2.8.1. Growth and growth components

Shantamallaiah *et al.* (1977) revealed that sunflower plant height was maximum (153cm) at 80 kg nitrogen with 40,000 plants ha⁻¹. Karami (1980) observed that the growth of sunflower was good at 150 kg N ha⁻¹ along with

50,000 plants ha⁻¹. Narwal and Malik (1985) reported increased plant height with higher N dose at closer spacing of 45 x 20cm. Plant height was maximum at higher level of N (80 kg ha⁻¹) with a plant spacing of 45 x 20cm (Bhola and Faroda, 1990).

Singhi and Pacheria (1981) reported that the stem girth of sunflower was maximum (1.76cm) at wider spacing (60 x 22.5 cm) with increased level of N (120 kg N ha⁻¹). However increased plant population progressively decreased the stem girth at 0 to 80 kg ha⁻¹ of N, but drymatter production were higher in lower plant populations with higher fertility levels (Hegde and Havanagi, 1987). Kene *et al.* (1993) and Tenbe *et al.* (1996) also reported that crop growth and drymatter accumulation of sunflower were higher at increased N and population levels.

2.8.2. Yield components

2.8.2.1. Head diameter

Ramaswamy *et al.* (1974) reported increased head diameter of sunflower at higher N (200 kg ha⁻¹) levels with lower plant population. Shantamallaiah *et al.* (1977) concluded that head diameter (21cm) were high at 30,000 plant ha⁻¹ with 80kg N ha⁻¹. Singhi and Pacheria (1981) found that lower plant population along with higher N level (120 kg ha⁻¹) produced greater head diameter. Kene *et al.* (1992) found that a plant spacing of 45 x 30 cm with 60 kg N ha⁻¹ produced higher head diameter. Similar results were also reported by Shaik Mohammad and Sagar (1983).

2.8.2.2. Number of filled seeds head⁻¹

Shantamallaiah *et al.* (1977) reported that the filled seeds capitulum⁻¹ were maximum (877) at 30,000 plants ha⁻¹ along with 80 kg N ha⁻¹. Narasimha Rao and

Narsa Reddy (1982) obtained more number of filled seeds under wider spacing at 90 kg N ha⁻¹. Kene *et al.* (1992) obtained more number of filled seeds in the presence of 40 kg N ha⁻¹ with 45 x 30 cm spacing.

2.8.2.3. Test weight

Shaik Mohammad and Sagar (1983) found that wider spacing of 60 x 60 cm at higher level of N improved the 1000 seed weight upto 76g. Increasing N level upto 80 kg ha⁻¹ with medium spacing of 45x30cm increased the test weight of sunflower (Bhola and Faroda, 1990).

2.8.2.4. Seed yield

Ramaswamy *et al.* (1974) noticed significant interaction effect of N and plant population on seed yield of sunflower. Higher seed yield (1020 kg ha⁻¹) was obtained at 60,000 plants ha⁻¹ with 80kg N ha⁻¹. However, increase in seed yield with 80 kg N ha⁻¹ was not significant over 60kg N ha⁻¹ at the same population level Shantamallaiah *et al.* (1977). Haribabu and Chauhan (1979) found that application of 120 kg N ha⁻¹ in two splits with 60x22.5 cm spacing gave significantly higher yield than closer spacing. The yield components were found to increase with lower plant population and higher fertility levels (Hussein *et al.*, 1980). This was mainly because of the fact that increase in seed weight and other components were compensated by more number of plants per unit area. Jadhawa and Jadhawa (1980) reported highest yield of sunflower at 45cm row spacing with 40kg N ha⁻¹.

Singhi and Pacheria (1981) reported that adopting a row spacing of 45cm with 105 kg N ha⁻¹ was better to get higher seed yield of sunflower. Higher seed yield (1921 kg ha⁻¹) was obtained with an interaction of 1,66,666 plants ha⁻¹ and 80 kg N + 80 kg P₂O₅ ha⁻¹ as compared to 27,777 plants ha⁻¹ and unfertilized plots

(Hegde and Havanagi, 1987). Results of higher sunflower yield at higher plant population and fertility levels have also been reported by Srinivas and Patil (1974); Narwal and Malik (1986); Patil *et al.* (1992).

Bhola and Faroda (1990) reported that 45x30cm plant spacing with 60 kg N gave the highest seed yield than other treatments. This is in conformity with the result obtained by Narwal and Malik (1985). Ujjinaiah *et al.* (1991) observed that maintaining a row spacing of 60cm with 75kg N ha⁻¹ was ideal to produce good quality of BSH-1 seeds with high vigour index. Bindra and Kharwara (1992) recorded higher seed yield of sunflower of 60 kg N ha⁻¹ with a plant spacing of 45x20cm. Similarly, increase in sunflower seed yield with N x plant population combination was reported by EL-sayed *et al.*, 1984; Kene *et al.*, 1993 and Bindra and Kharwara, 1994.

Bhoite and Nimbalkar (1995) reported that sunflower seed yield was not affected by plant spacing but a positive interaction effect was observed with plant population and N and P nutrient levels. Tenbe *et al.* (1996) observed that interaction of N x plant population confounded the main effect of each factor on the yield of sunflower. They found that the seed yield (3425 kg ha⁻¹) obtained from the use of 100 kg N ha⁻¹ at 80,000 plant ha⁻¹ was significantly higher than those obtained from all other combination of N x plant population.

Massey (1971) in a study with graded doses of nitrogen (0, 56, 112 and 168 kg N ha⁻¹) at varied plant population levels (60,606, 30,303 and 19,762 plants ha⁻¹) noticed no significant interaction between N and plant population on any of the economical characters studied but individual effects of N and plant population were apparent.

However, Singh and Kaushal (1975) did not observe any significant interaction effect of nitrogen and plant population on seed yield of sunflower.

2.8.2.g. Seed protein and oil content

Srinivas and Patil (1974) revealed that the seed protein content increased from 21.65 to 24.25 per cent with increasing levels of N from 40 to 80 kg N ha⁻¹. An increase in N levels (0 to 200 kg N ha⁻¹) significantly reduced the percentage of oil in sunflower achenes (Karami, 1980). Similar results were also reported by Robinson *et al.* (1980).

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

Field experiments were conducted under rainfed conditions at the TamilNadu Agricultural University farm, Coimbatore, during North East Monsoon (NEM) seasons of 1997 and 1998 with the objective of studying the influence of plant population and split application of nitrogen on sunflower var. Co2. The details of the materials used and methods adopted during the course of the investigation are presented here under.

3.1. Materials

3.1.1. Location of the experimental site

The experiments were conducted in Field No. 36c (Eastern Block), Department of Agronomy, TamilNadu Agricultural University, Coimbatore which is situated in the North western agroclimatic zone of TamilNadu at 11°N latitude and 77°E longitude and at an altitude of 426.7 M above mean sea level.

3.1.2. Weather and climate

Coimbatore receives a mean annual rainfall of 674.2 mm in 45.8 rainy days. The mean maximum and minimum temperature are 31.5°C and 21.0°C respectively. The relative humidity ranges from 61 to 91 per cent and 14 to 68 per cent during forenoon and afternoon, respectively. The mean bright sunshine received is 7.3 hours day⁻¹ with a mean solar radiation of 429 Cal⁻¹ Cm⁻² day⁻¹.

The amount of rainfall received during the cropping period was 598 mm and 571.2 mm distributed over 43 and 20 rainy days during 1997 and 1998

respectively. The weather conditions prevailed during the study period are furnished in appendix I and II and depicted in figure 1 and 2.

3.1.3. Soil characteristics

The soil of the experimental field is deep, moderately well drained clay loam and low in available N, medium in available P and high in available K status. The details of soil analysis are given in Table 1.

3.1.4. Season

The crop was raised during the North East Monsoon season (September to December) of 1997 and 1998.

3.1.5. Crop and variety

Sunflower var. Co2 released by TamilNadu Agricultural University, was chosen for the study. The varietal characters are presented in Table 2.

3.2. Methods

3.2.1. Design of Layout

The experiment was laid out in split plot design with three replications. The main plots consisted of three plant population levels and the sub plots included split application of nitrogen at different stages. The experimental layout is presented in Fig.3 and 4.

3.2.2. Treatment details

The treatments followed for the experiments are given below:

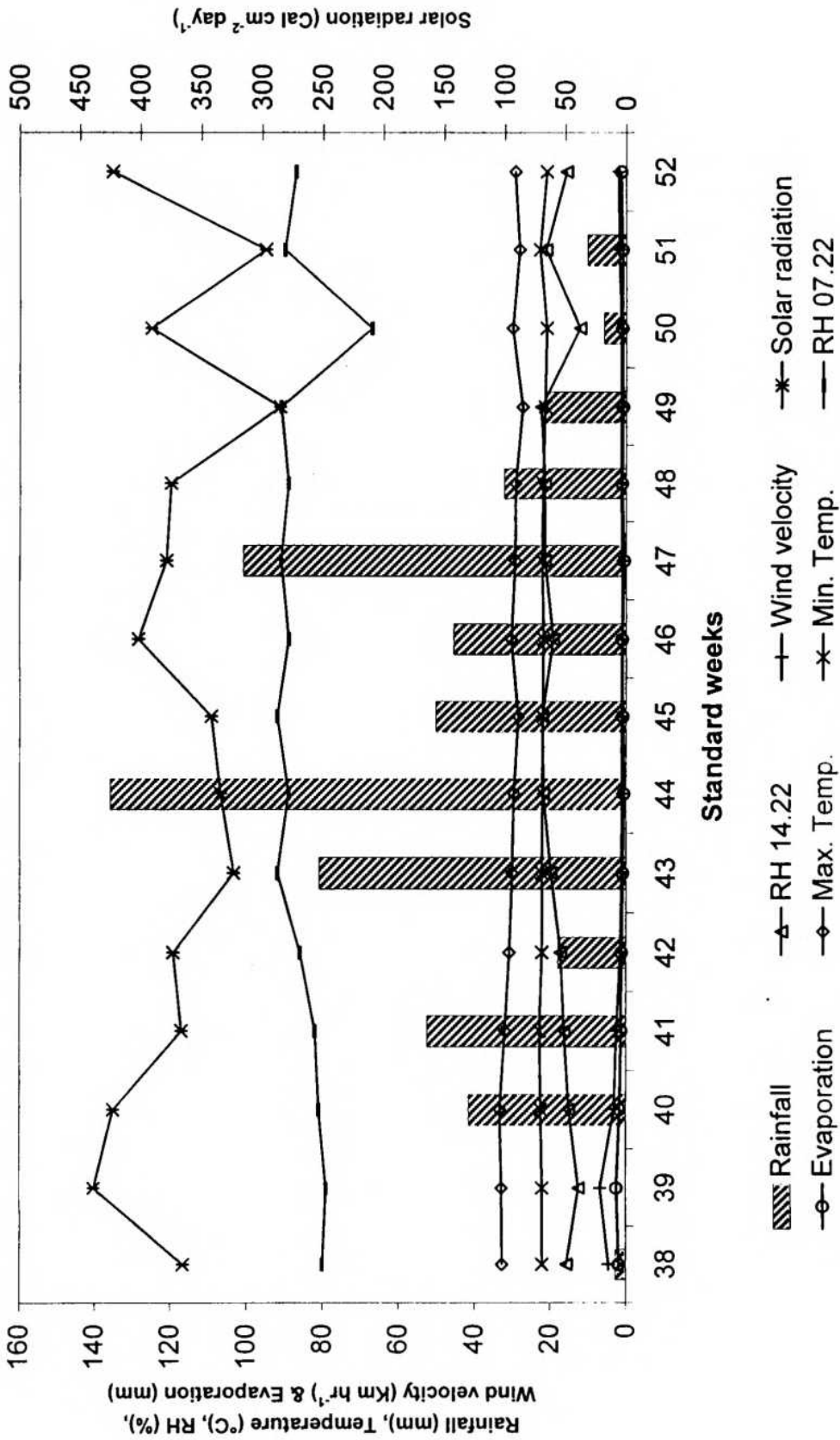


Fig. 1. Weather data - NEM 1997

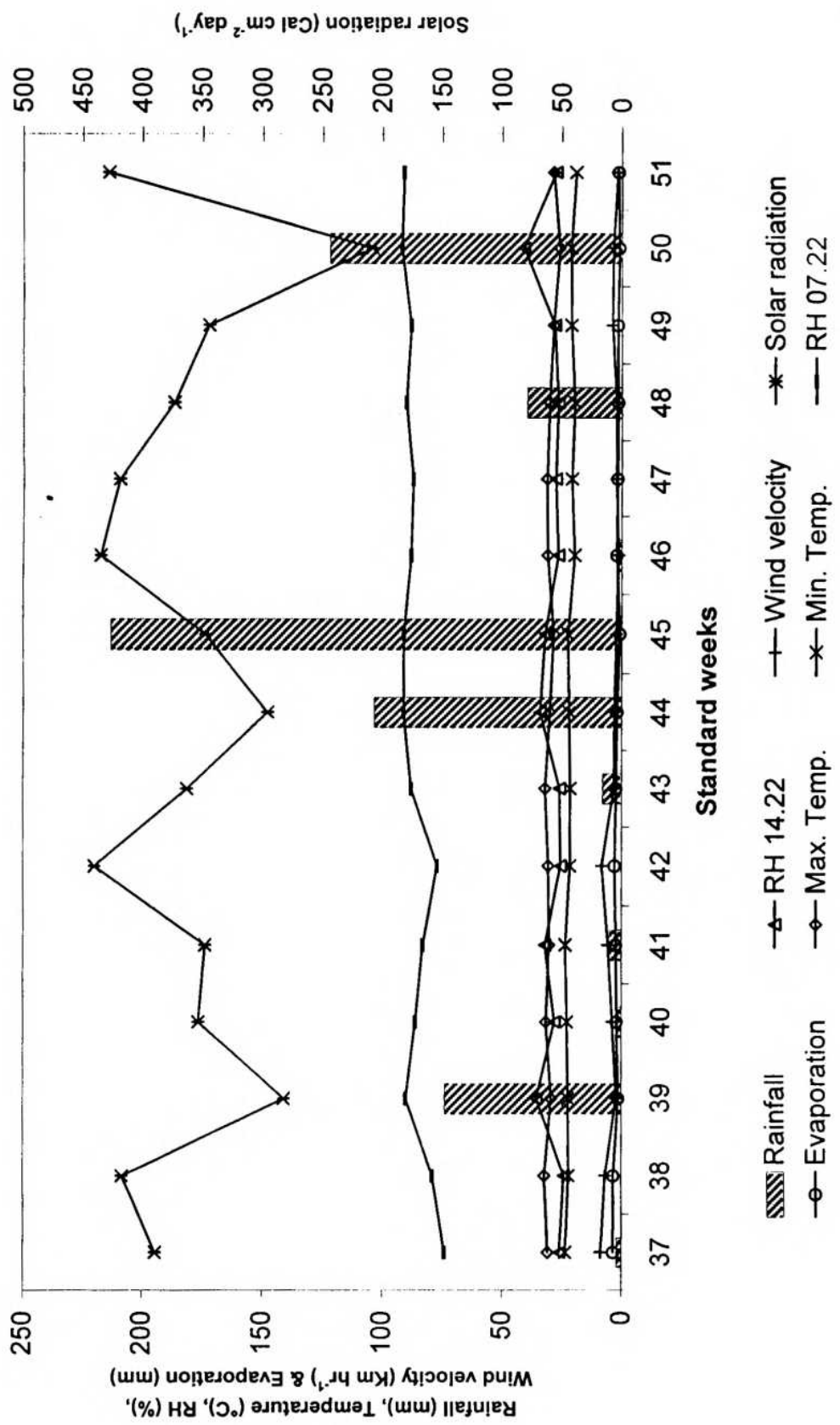


Fig. 2. Weather data - NEM 1998

I Main plot : (Plant population)

P₁ : 80% of recommended plant population (30 x 37.5 cm)

P₂ : 100% of recommended plant population (30 x 30 cm)

P₃ : 120% of recommended plant population (30 x 25 cm)

II Sub plot : (Nitrogen split application)

N₁ : Full basal (100% of recommended N*)

N₂ : ½ basal + ½ on 4th week after sowing with rain

N₃ : ½ basal + ½ on 6th week after sowing with rain

N₄ : ½ basal + ¼ on 4th week after sowing + ¼ on 6th week after sowing with rain

N₅ : ⅓ basal + ⅓ on 4th week after sowing + ⅓ on 6th week after sowing with rain

N₆ : ¼ basal + ½ on 4th week after sowing + ¼ on 6th week after sowing with rain

* 100% of recommended N = 40 kg ha⁻¹.

3.2.3. Experimental particulars

	<u>NEM 1997</u>	<u>NEM 1998</u>
Gross plot size (m ²)	5 x 4 m ²	5 x 4 m ²
Net plot size (m ²)	4.5 x 3.0 m ²	4.5 x 3.0 m ²
Date of sowing	18-9-97	12-9-98
Date of harvest	30-12-97	21-12-98

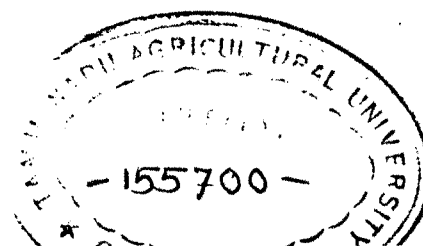


Table 1. Soil characteristics of the experimental site

Particulars	Field No.36C	
	NEM 1997	NEM 1998
A. Mechanical analysis (Piper, 1966)		
a. Coarse sand (%)	27.82	27.27
b. Fine sand (%)	24.38	24.73
c. Silt (%)	18.31	18.29
d. Clay (%)	29.40	29.66
e. Texture	Sandy clay loam	Sandy clay loam
B. Physical properties (Piper, 1966)		
a. Field capacity (%)	23.80	24.30
b. Permanent wilting point (%)	11.60	11.80
c. Bulk density (gm^{-3})	1.41	1.40
C. Chemical properties		
a. EC (dsm^{-1})	0.40 (at 15 cm depth)	0.42 (at 15 cm depth)
(1 : 2 Soil Water suspension) (Jackson, 1973)	0.32 (at 30 cm depth)	0.30 (at 30cm depth)
b. pH	8.4 (at 15 cm depth)	8.2 (at 15 cm depth)
(1 : 2 Soil Water suspension) (Jackson, 1973)	8.8 (at 30 cm depth)	8.7 (at 30 cm depth)
c. Available Nitrogen (Kg ha^{-1}) (Subbaiah and Asija, 1956)	224 Kg N ha^{-1}	210 kg N ha^{-1}
d. Available Phosphorus (Kg ha^{-1}) (Olsen <i>et al.</i> , 1954)	18 $\text{P}_2\text{O}_5 \text{ ha}^{-1}$	17.5 $\text{P}_2\text{O}_5 \text{ ha}^{-1}$
e. Available Potassium (Kg ha^{-1}) (Stanford and English, 1949)	460 $\text{Kg K}_2\text{O ha}^{-1}$	465 $\text{Kg K}_2\text{O ha}^{-1}$

Table 2. Varietal characters of sunflower (TNAU, 1990)

Variety	:	Co2
Parentage	:	Pedigree selection from Rumanian hybrids (EC 116208, EC 116209, EC 116210, EC 116211, EC 116212, EC 116213 and EC 116214)
Duration (days)	:	87
Plant height (cm)	:	135
Stem	:	Profusely hairy
Leaves	:	Large, green
Head	:	Medium, large
Head diameter (cm)	:	15
Hundred seed weight (g)	:	6.53
Seed colour	:	Medium dark grey
Seed shape	:	Oval, linear
Oil-content (per cent)	:	37.4
Yield : Rainfed (kg ha ⁻¹)	:	900
Irrigated (Kg ha ⁻¹)	:	1400



FIG.3 : FIELD LAYOUT PLAN
NEM 1997

	R I		R II		R III	
	P ₃ N ₂	P ₃ N ₁	P ₂ N ₂	P ₂ N ₅	P ₁ N ₄	P ₁ N ₅
	P ₃ N ₆	P ₃ N ₅	P ₂ N ₆	P ₂ N ₃	P ₁ N ₆	P ₁ N ₂
	P ₃ N ₄	P ₃ N ₃	P ₂ N ₁	P ₂ N ₄	P ₁ N ₃	P ₁ N ₁
	P ₁ N ₃	P ₁ N ₄	P ₁ N ₆	P ₁ N ₂	P ₃ N ₁	P ₃ N ₅
	P ₁ N ₅	P ₁ N ₁	P ₁ N ₁	P ₁ N ₅	P ₃ N ₆	P ₃ N ₂
	P ₁ N ₂	P ₁ N ₆	P ₁ N ₄	P ₁ N ₃	P ₃ N ₃	P ₃ N ₄
	P ₂ N ₄	P ₂ N ₁	P ₃ N ₃	P ₃ N ₄	P ₂ N ₂	P ₂ N ₅
	P ₂ N ₃	P ₂ N ₆	P ₃ N ₅	P ₃ N ₆	P ₂ N ₆	P ₂ N ₃
↓ 5M ↑	P ₂ N ₅	P ₂ N ₂	P ₃ N ₁	P ₃ N ₂	P ₂ N ₁	P ₂ N ₄
	→ 4M ←					

FIG.4 : FIELD LAYOUT PLAN
NEM 1998



	R I		R II		R III	
	P ₃ N ₂	P ₃ N ₃	P ₁ N ₂	P ₁ N ₅	P ₂ N ₄	P ₂ N ₃
	P ₃ N ₅	P ₃ N ₆	P ₁ N ₆	P ₁ N ₃	P ₂ N ₆	P ₂ N ₅
	P ₃ N ₄	P ₃ N ₁	P ₁ N ₄	P ₁ N ₁	P ₂ N ₂	P ₂ N ₁
	P ₂ N ₄	P ₂ N ₁	P ₃ N ₁	P ₃ N ₆	P ₃ N ₂	P ₃ N ₆
	P ₂ N ₂	P ₂ N ₆	P ₃ N ₂	P ₃ N ₃	P ₃ N ₅	P ₃ N ₃
	P ₂ N ₃	P ₂ N ₅	P ₃ N ₄	P ₃ N ₅	P ₃ N ₄	P ₃ N ₁
	P ₁ N ₄	P ₁ N ₂	P ₂ N ₅	P ₂ N ₁	P ₁ N ₂	P ₁ N ₅
	P ₁ N ₃	P ₁ N ₁	P ₂ N ₃	P ₂ N ₂	P ₁ N ₃	P ₁ N ₁
↓ 5M ↑	P ₁ N ₆	P ₁ N ₅	P ₂ N ₆	P ₂ N ₄	P ₁ N ₆	P ₁ N ₄
	→ 4M ←					

3.2.4. Preparation of the field

The field was ploughed with tractor drawn disc plough and then harrowed. Beds are formed by bullock drawn bund former and then corrected by manual labour.

3.2.5. Seed treatment

The seeds were treated with “Thiram” at the rate of 2 g kg⁻¹ of seed against seed borne diseases.

3.2.6. Seeds and sowing

The seeds were sown by dibbling at 2 to 3 seeds hill⁻¹ with a row spacing of 30cm and plant spacing as per the treatment schedule.

3.2.7. Fertilizer application

The recommended N, P and K at 40 : 20 : 20 kg ha⁻¹ was applied as urea (46% N), single super phosphate (16% P₂O₅) and muriate of potash (60% K₂O), respectively. Nitrogen was applied in splits as per the treatment schedule. Full dose of P₂O₅ and K₂O were applied basally to all the treatments. In 1997, for N₄ treatment N fertilizer was applied with receipt of 21.85 mm of rainfall on 31.10.97 (4th week after sowing). The same treatment received N fertilizer with receipt of 45.5 mm of rainfall on 17.11.97 (6th week after sowing). In 1998, for N₂ treatment, N fertilizer was applied with receipt of 24.8 mm of rainfall on 29.10.98 (4th WAS) and the same treatment received N fertilizer with receipt of 29.5 mm of rainfall on 11.11.98 (6th WAS). The dates of fertilizer application were given as under.

Treatment	Date of fertilizer application					
	1997			1998		
	Basal	I split	II split	Basal	I split	II split
N1	6.10.97	-	-	26.9.98	-	-
N2	6.10.97	2.11.97	-	26.9.98	30.10.98	-
N3	6.10.97	-	19.11.97	26.9.98	-	14.11.98
N4	6.10.97	2.11.97	19.11.97	26.9.98	30.10.98	14.11.98
N5	6.10.97	2.11.97	19.11.97	26.9.98	30.10.98	14.11.98
N6	6.10.97	2.11.97	19.11.97	26.9.98	30.10.98	14.11.98

3.3. Intercultural operations

3.3.1. Gap filling and thinning

Gap filling was done on fifth day after sowing. Thinning was done on the 15th day after sowing maintaining one healthy plant hill⁻¹.

3.3.2. Weed control

Fluchloralin as pre-emergence herbicide was sprayed at the rate of 2.0 lit ha⁻¹ on third day after sowing. One hand hoeing and weeding was given on 25 DAS.

3.3.3. Plant protection

Endosulfan 35 EC, at the rate of 1.0 lit ha⁻¹ was sprayed on 45 DAS against Capitulum borer (*Helicoverpa armigera*).

3.3.4. Harvesting and threshing

The crop was harvested at full maturity indicated by the change of colour of the perianth from green to golden yellow. The capitulum of border plants on all

the sides of the plots were harvested first and pooled together. The net plots were harvested separately and dried. Threshing of the capitulum was done manually and after cleaning, the yield of seeds were recorded.

3.4. Biometric observations

Within the net plot area, five plants were selected at random, tagged and subsequently used for recording the biometric observations. Biometric observations were recorded at 30 and 50 DAS and at harvest.

3.4.1. Growth components of sunflower

3.4.1.1. Plant height

The plant height was measured in the five tagged plants from the ground level to the top most leaf at 30 and 50 DAS and at harvest and expressed in cm.

3.4.1.2. Stem girth

The girth of the stem at 30 DAS and 50 DAS and at harvest was recorded at the lowest node by using a thread and expressed in cm.

3.4.1.3. Dry matter production (DMP)

Five plants were cut close to the ground from the sample rows at random in each plot at 30 and 50 DAS and at harvest. The samples were air dried and then oven dried at 60°C till a constant weight was recorded. The weight of the oven dried samples was recorded and dry matter production (DMP) was expressed in kg ha⁻¹.

3.4.2. Growth analysis

3.4.2.1. Leaf area index (LAI)

The leaf area was calculated by multiplying the length and width of the leaf with the factor 0.73 (Rauoson, 1980). The leaf area index was calculated by dividing the total leaf area of the plant divided by the land area occupied.

3.4.2.2. Crop growth rate (CGR)

The CGR during the growth period (30-50 DAS and 50 DAS to harvest) was calculated as suggested by Buttery (1970)

$$\text{CGR} = \frac{W_2 - W_1}{P (t_2 - t_1)} \quad \text{gm}^{-2} \text{ day}^{-1}$$

W_1 and W_2 = Initial and final dry weight of plant material per unit ground area (g)

t_1 and t_2 = Initial and final days of observation

P = Ground area

3.4.2.3. Relative growth rate (RGR)

The RGR during crop growth period (30-50 DAS and 50 DAS to harvest) was calculated as suggested by Enyi (1962) and expressed in $\text{mg g}^{-1} \text{ day}^{-1}$.

$$\text{RGR} = \frac{(\log_e W_2 - \log_e W_1)}{t_2 - t_1} \quad \text{mg g}^{-1} \text{ day}^{-1}$$

W_1 and W_2 = Initial and final dry weight of plant material per unit ground area (g)

t_1 and t_2 = Initial and final days of observation

3.4.2.4. Net assimilation rate (NAR)

The NAR during the crop growth period (30-50 DAS and 50 DAS to harvest) was worked out as suggested by Enyi (1962) and expressed in $\text{cm}^2 \text{g}^{-1} \text{day}^{-1}$.

$$\text{NAR} = \frac{(W_2 - W_1) (\log_e L_2 - \log_e L_1)}{(t_2 - t_1) (L_2 - L_1)} \text{ cm}^2 \text{g}^{-1} \text{day}^{-1}$$

W_1 and W_2 = Initial and final dry weight of plant material per unit ground area (g)

t_1 and t_2 = Initial and final days of observation

L_1 and L_2 = Initial and final leaf area (cm^2)

3.4.2.5. Days to fifty per cent flowering

The number of days taken for 50 per cent of plants to show flower from the heads was recorded in each treatment.

3.4.3. Yield components

3.4.3.1. Head (capitulum) diameter

The diameter of five labeled flower heads per plot were measured at harvest and the mean was taken and expressed in cm.

3.4.3.2. Percentage of filled seeds

The ratio of filled seeds to the total number of seeds capitulum⁻¹ was recorded and expressed in per cent.

3.4.3.3.3. Total number of seeds head⁻¹

Number of filled and unfilled seeds from the labelled heads were counted and recorded.

3.4.3.4. Hundred seed weight

One hundred filled seeds were counted from the heads of each plot and their weight was recorded in gram.

3.4.3.5. Seed yield

Seed yield from each net plot area was recorded at 14 per cent moisture level and expressed in kg ha⁻¹.

3.5. Chemical analysis

The oven dry samples of plant materials were ground in a willey mill and analysed for N, P and K contents. The uptake of NPK was worked out by multiplying the nutrient content with the corresponding dry matter produced per unit area and expressed in kg ha⁻¹.

3.5.1. Nitrogen

The total nitrogen content in the plant sample was estimated by the microkjeldahl method as suggested by Yoshida *et al.* (1971). The uptake was calculated by multiplying the N content of the plant sample with the corresponding total dry matter and expressed in kg ha⁻¹.

3.5.2. Phosphorous

The total phosphorus content was estimated with triple acid digestion method as described by Jackson (1973). The estimation was done colorimetrically

using photoelectric colorimeter. The uptake was calculated by multiplying the phosphorus content of the plant sample with the total dry matter and expressed in kg ha^{-1} .

3.5.3. Potassium

The total potassium content was estimated by the triple acid digestion method using flame photometer as suggested by Jackson (1973). The uptake was calculated by multiplying the potassium content of the plant sample with the total dry matter and expressed in kg ha^{-1} .

3.5.4. Crude protein content of seed

Seed samples were taken from each plot and analysed for total N by microkjeldhal method. The N content of the seed was multiplied by the factor 6.25 to get the crude protein content and expressed in per cent.

3.5.5. Oil content.

Oil content of seeds was estimated by using Nuclear Magnetic Resonance (NMR) spectrometer (Bruter Minispe P₂O model) against a standard reference sample (Granlund and Zimmerman, 1975).

3.5.6. Oil yield

Oil yield was worked out by multiplying the oil content with seed yield and expressed in kg ha^{-1} .

3.6. Soil analysis

3.6.1. Available soil Nitrogen (N)

Available soil was estimated by the method described by Subbaiah and Asija (1956).

3.6.2. Available soil phosphorus

Soil available P was determined as described by Olsen *et al.* (1954).

3.6.3. Available soil potassium (K)

Soil available K was estimated by neutral normal ammonium acetate extraction method using flame photometry (Stanford and English, 1949).

3.7. Soil moisture estimation

Soil moisture content was estimated at fortnightly intervals at two depths *viz.*, 0-15 cm, 15-30 cm by gravimetric method. Available soil moisture in mm. was arrived at by multiplying the moisture content with bulk density.

3.8. Economics

The economics for different treatments was worked out based on the input, labour and produce costs followed at TamilNadu Agricultural University farm. Based on the gross return and total cultivation cost, the net return (Rs. ha⁻¹) and benefit cost ratio were worked out.

3.9. Statistical Analysis

The data collected were analysed statistically following the procedure given by Gomez and Gomez (1984). Wherever the treatment differences were significant, critical differences were worked out at five per cent probability level.

Experimental Results

CHAPTER IV

RESULTS

Field experiments were conducted at Tamil Nadu Agricultural University, Coimbatore, to study the effect of plant population and N split application on sunflower under rainfed condition during North east monsoon seasons of 1997 and 1998. The results of the experiments are presented in this chapter.

4.1. Growth components

4.1.1. Plant height

The data on plant height of sunflower recorded at 30 and 50 DAS and at harvest are presented in Table 3.

Sunflower under closer spacing at P₃ (30 x 25 cm) grew taller than that of the wider spacing of P₁ (30 x 37.5 cm) at all the stages of crop growth in North East monsoon season of 1997 and 1998. Plant height rapidly increased during the period from 30 to 50 DAS and thereafter, the increase was marginal upto maturity.

In 1997, at 30DAS and at harvest, plants at P₃ spacing recorded 21.6 and 9.5 per cent higher plant height than P₁ and P₂ (30 x 30 cm). At 50 DAS, P₃ showed superiority with 7.2% more plant height over P₂ and was comparable with each other.

In 1998, P₃ population level was significantly superior in recording higher plant height over P₂ and P₁, at all the stages of crop growth, with an increase of 7.8, 7.1 and 10.8 per cent over at 30, 50 DAS and at harvest stages, respectively.

Table 3. Effect of plant population and nitrogen split application on plant height (cm) of sunflower.

Treatments				NEM - 1997			NEM - 1998		
				30DAS	50DAS	Harvest	30DAS	50DAS	Harvest
Plant spacing									
P ₁ :30 x 37.5 cm				34.04	122.66	141.91	28.59	126.78	139.45
P ₂ :30 x 30cm				37.68	130.56	141.06	29.84	128.28	144.54
P ₃ :30 x 25cm				41.40	134.31	151.34	30.82	135.76	154.53
SEd				1.37	3.16	2.42	0.23	1.88	0.83
CD (P=0.05)				3.80	8.77	6.72	0.65	5.21	2.30
Split application of N									
	Basal	4 th WAS	6 th WAS						
N ₁	Full	-	-	38.37	119.43	134.04	31.43	131.92	147.32
N ₂	½	½	-	38.32	130.98	145.46	29.69	133.69	151.98
N ₃	½	-	½	36.43	128.83	146.61	29.97	125.22	139.49
N ₄	½	¼	¼	37.67	134.46	148.66	29.33	129.75	145.17
N ₅	1/3	1/3	1/3	36.97	130.91	146.54	28.98	128.80	144.92
N ₆	¼	½	¼	38.46	130.44	146.30	29.13	132.28	148.16

SEd 0.93 2.67 2.97 0.63 1.36 0.27

CD(P=0.05) NS 5.45 6.07 1.29 2.79 0.56

WAS - Weeks after sowing

DAS - Days after sowing

Regarding split application of nitrogen, plant height at 30 DAS in 1997 was not significant. At 50 DAS and at harvest, N₄ ($\frac{1}{2}$ basal + $\frac{1}{4}$ on 4th week after sowing + $\frac{1}{4}$ on 6th week after sowing with rain) recorded 12.5 and 10.9 per cent higher plant height respectively than N₁ and was on par with all other treatments.

In 1998, at 30 DAS, N₁ (Full basal) had produced significantly higher plant height than N₅, followed by N₃ which was on par with all other treatments (N₂, N₄, N₆ and N₅). At 50 DAS, the treatment N₂ showed its superiority over other treatments and was at par with N₆ and N₁. The same trend was noticed at harvest stage wherein N₂ treatment was independently significant than others with an increase in plant height of 8.9 per cent over N₃.

4.1.2. Stem girth

The mean data on stem girth recorded at 30 and 50 DAS and at harvest are presented in Table 4.

In 1997, at 30 DAS, P₁ (30 x 37.5 cm) treatment was significantly superior from P₂ (30 x 30 cm) and P₃ (30 x 25 cm). At 50 DAS and at harvest, stem girth at P₁ was significantly superior over others, while the same in P₂ and P₃ treatments were comparable. At all the stages of crop growth, P₁ produced higher stem girth than P₃ which was 16.9, 32.3 and 25.9 per cent more at 30, 50 DAS and at harvest stages respectively.

In 1998, P₁ was superior than P₃ by 16.5, 15.9 and 24.9 per cent at 30, 50 DAS and at harvest, respectively. Each plant populations were individually significant in all the stages of crop growth.

Table 4. Effect of plant population and nitrogen split application on stem girth (cm) of sunflower.

Treatments	NEM - 1997			NEM - 1998					
	30DAS	50DAS	Harvest	30DAS	50DAS	Harvest			
Plant spacing									
P ₁ :30 x 37.5 cm	3.17	5.81	6.27	4.02	6.39	7.16			
P ₂ :30 x 30cm	2.90	4.45	5.16	3.71	5.83	6.09			
P ₃ :30 x 25cm	2.71	4.39	4.98	3.45	5.51	5.73			
SEd	0.04	0.17	0.17	0.06	0.08	0.03			
CD (P=0.05)	0.12	0.48	0.46	0.16	0.22	0.09			
Split application of N									
	Basal	4 th WAS	6 th WAS						
N ₁	Full	-	-	2.87	4.50	4.90	4.13	6.01	6.44
N ₂	½	½	-	2.83	5.05	5.55	3.85	6.24	6.85
N ₃	½	-	½	2.97	4.87	5.61	3.68	5.31	5.53
N ₄	½	¼	¼	2.93	4.99	5.68	3.72	5.96	6.37
N ₅	1/3	1/3	1/3	2.91	4.9	5.45	3.52	5.92	6.30
N ₆	¼	½	¼	2.95	4.99	5.62	3.43	6.02	6.48
SEd				0.93	0.15	0.13	0.07	0.03	0.04
CD(P=0.05)				NS	0.32	0.27	0.15	0.06	0.09
WAS	-	Weeks after sowing							
DAS	-	Days after sowing							

In 1997, split application of N at 30 DAS did not show any significant change in stem girth. At 50 DAS, N₂ proved superior by 12.2 per cent than N₁ and it was on par with all other N applications. At harvest, N₄ recorded significantly higher stem girth by 15.9 per cent over N₁ and was on par with N₆, N₃, N₂ and N₅.

In 1998 at 30 DAS, the stem girth at N₁ was significantly superior than N₆ by 20.4 per cent and was followed by N₂, N₄, N₃ and N₅. At 50 DAS, N₂ recorded significantly higher stem girth than N₃. At harvest N₂ recorded 23.8 per cent higher stem girth than N₃ and N₆ was on par with N₁ and N₄.

4.1.3. Dry matter production (DMP)

The mean data on DMP recorded at 30 and 50 DAS and at harvest are presented in Table 5, 6 and 7 (Fig. 5 and 6).

In general, higher plant population produced more biomass accumulation at all the stages of crop growth in both the years. However, individual plant weight was less at higher plant population level when compared to lower population levels.

In 1997, at 30 DAS, P₃ plant population (30 x 25 cm) produced more drymatter which was 11.1 per cent higher than P₁ (30 x 37.5 cm). At 50 DAS and at harvest, P₃ plant population produced more drymatter than P₁ and the increase was 13.1 and 11.2 per cent respectively.

In 1998, at all the stages of crop growth, P₃ produced significantly higher drymatter accumulation than P₁ with 4.8, 6.2 and 5.2 per cent more value at 30, 50 DAS and at harvest respectively.

Table 5. Effect of plant population and split application of nitrogen on dry matter production (kg ha^{-1}) at 30 DAS

Treatments	Plant spacing									
	NEM 1997					NEM 1998				
	P ₁	P ₂	P ₃	Mean	P ₁	P ₂	P ₃	Mean		
Split application of N										
N ₁	687	731	760	726	751	766	797	771		
N ₂	682	729	756	722	736	749	778	754		
N ₃	681	730	757	723	730	744	771	748		
N ₄	682	730	760	724	735	742	772	750		
N ₅	681	728	759	723	728	736	752	738		
N ₆	682	729	760	723	719	728	741	729		
Mean	683	729	759	-	733	744	768	-		

SEd

CD (P=0.05)

SEd

CD (P=0.05)

9

26

28

10

13

26

NS

21

15

NS

NS

42

15

NS

NS

41

Table 6. Effect of plant population and split application of nitrogen on dry matter production (kg ha^{-1}) at 50 DAS

Treatments	Plant spacing									
	NEM 1997				NEM 1998					
	P ₁	P ₂	P ₃	Mean	P ₁	P ₂	P ₃	Mean	Mean	
Split application of N										
N ₁	3407	3758	3880	3682	4108	4280	4385	4258		
N ₂	3528	3831	3941	3767	4381	4436	4665	4494		
N ₃	3411	3757	3853	3674	3963	4095	4281	4113		
N ₄	3501	3857	3915	3758	4142	4243	4362	4249		
N ₅	3507	3884	4002	3797	4111	4228	4305	4215		
N ₆	3510	3877	4016	3801	4217	4311	4522	4368		
Mean	3477	3827	3935	-	4163	4266	4420	-		

	SEd	CD (P=0.05)	SEd	CD (P=0.05)
P	43	118	8	24
N	38	78	49	100
P at N	48	NS	78	NS
N at P	50	NS	85	NS

Table 7. Effect of plant population and split application of nitrogen on dry matter production (kg ha^{-1}) at harvest

Treatments	Plant spacing								
	NEM 1997					NEM 1998			
	P ₁	P ₂	P ₃	Mean	P ₁	P ₂	P ₃	Mean	
Split application of N									
N ₁	6288	6510	7570	6789	7658	7759	8030	7816	
N ₂	7133	7253	8037	7474	7835	7993	8235	8021	
N ₃	7237	7343	8022	7534	7410	7530	7845	7595	
N ₄	7479	7557	8109	7715	7534	7698	7955	7729	
N ₅	7554	7648	8268	7823	7533	7665	7905	7701	
N ₆	7497	7752	8018	7756	7715	7817	8118	7883	
Mean	7198	7344	8004	-	7614	7744	8015	-	

	SEd	CD (P=0.05)	SEd	CD (P=0.05)
P	19	52	16	44
N	21	43	34	69
P at N	38	85	59	NS
N at P	37	75	56	NS

In 1997, nitrogen at different split applications at 30 DAS was not significant among themselves. At 50 DAS, N₆ proved its superiority over N₃ by registering 3.5 per cent higher DMP and was comparable with N₅. At harvest stage, N₅ treatment proved superior than N₁ with 15.2 per cent higher drymatter accumulation and was followed by N₆ treatment which was at par with N₄.

In 1998, at 30 DAS, N₁ treatment proved significantly superior showing 5.7 per cent higher dry matter accumulation than N₆ followed by N₂ which was comparable with N₄ and N₃. At 50 DAS and at harvest, N₂ was found superior than N₃ which recorded 9.2 and 5.6 per cent increased dry matter production at 50 DAS and at harvest stages respectively.

4.2. Growth analysis

4.2.1. Leaf area index (LAI)

The mean data on LAI at 30 and 50 DAS and at harvest stages are presented in Table 8 (Fig. 7 and 8).

Plant population exerted a significant influence on leaf area index at all the stages of crop growth in both the years. In 1997, at all the stages of crop growth, P₃ (30 x 25 cm) was significantly superior than P₁ (30 x 37.5 cm) with 40, 42 and 51 per cent higher LAI at 30, 50 DAS and at harvest stages respectively. At 30 DAS, LAI at P₂ (30 x 30 cm) was comparable with P₁ while at other stages of crop growth, each treatment was independently superior to others. In 1998 also, P₃ plant population showed a significant increase in LAI and the increase was 39.2, 34.8 and 33.7 per cent at 30, 50 DAS and at harvest stages, respectively.

In 1997, at 30 DAS and at harvest, split application of N showed no significant difference in LAI of sunflower. But at 50 DAS, LAI at N₅ was

Table 8. Effect of plant population and N split application on leaf area index of sunflower.

Treatments	NEM - 1997			NEM - 1998					
	30DAS	50DAS	Harvest	30DAS	50DAS	Harvest			
Plant spacing									
P ₁ :30 x 37.5 cm	1.35	5.78	4.39	1.070	5.68	2.93			
P ₂ :30 x 30cm	1.58	6.75	5.09	1.230	6.71	3.63			
P ₃ :30 x 25cm	1.89	8.23	6.63	1.490	7.66	3.92			
SEd	0.10	0.21	0.19	0.003	0.03	0.07			
CD (P=0.05)	0.27	0.58	0.52	0.008	0.09	0.17			
Split application of N									
	Basal	4 th WAS	6 th WAS						
N ₁	Full	-	-	1.67	6.32	4.86	1.310	6.46	3.39
N ₂	½	½	-	1.61	7.06	5.56	1.270	7.26	4.09
N ₃	½	-	½	1.61	6.69	5.30	1.260	4.71	3.20
N ₄	½	¼	¼	1.62	6.98	5.36	1.260	7.26	3.47
N ₅	1/3	1/3	1/3	1.56	7.26	5.59	1.250	7.25	3.43
N ₆	¼	½	¼	1.59	7.22	5.55	1.240	7.17	3.36

SEd 0.05 0.28 0.25 0.003 0.07 0.09

CD(P=0.05) NS 0.57 NS 0.005 0.15 0.19

WAS - Weeks after sowing

DAS - Days after sowing

significantly superior to N_1 by producing 14.8 per cent more LAI and was comparable with all other N treatments (N_6 , N_2 , N_4 and N_3). In 1998, at 30 DAS, N_1 was significantly superior by producing 5.6 per cent increased LAI than N_6 followed by N_2 which was comparable with N_3 , N_4 and N_5 . At 50 DAS and at harvest, N_2 treatment was found to be superior than N_3 which produced 54 and 27 per cent increased leaf area index respectively. At 50 DAS, LAI at N_2 treatment was at par with other treatments in the order of N_4 , N_5 and N_6 . At harvest, N_2 was significantly superior with higher LAI followed by N_4 which was at par with N_5 , N_2 and N_6 .

4.2.2. Crop growth rate (CGR)

The mean data on crop growth rate recorded at 30 to 50 DAS and 50 DAS to harvest stages are presented in Table 9.

The crop growth rate was maximum at closer spacing of P_3 (30 x 25 cm) at all the stages in both the years. In 1997, P_3 treatment proved its superiority significantly, recording 14.2 and 9.2 per cent more crop growth rate than P_1 (30 x 37.5 cm) between 30 to 50 DAS and 50 DAS to harvest stages respectively.

In 1998, at 30 to 50 DAS, P_3 treatment recorded significant increase in crop growth rate which was 6.6 per cent higher than P_1 . At 50 DAS to harvest, P_3 was significantly superior showing 4 per cent higher CGR, while P_1 (30 x 37.5 cm) and P_2 were comparable.

Split application of N exhibited significant increase in crop growth rate at all the stages of crop in 1997. At 30 to 50 DAS, N_6 was superior than N_3 showing 4.3 per cent higher CGR and it was comparable with N_5 . While at 50 DAS to

Table 9. Effect of plant population and split application of N on CGR ($\text{g m}^{-2} \text{ day}^{-1}$)

Treatments	NEM - 1997		NEM - 1998	
	30-50 DAS	50DAS - Harvest	30-50 DAS	50DAS - Harvest
Plant spacing				
P ₁ :30 x 37.5 cm	13.90	10.62	17.11	9.83
P ₂ :30 x 30cm	15.54	10.04	17.58	9.92
P ₃ :30 x 25cm	15.88	11.61	18.25	10.23
SEd	0.03	0.07	0.04	0.04
CD (P=0.05)	0.09	0.20	0.12	0.10
Split application of N				
	Basal	4 th WAS	6 th WAS	
N ₁	Full	-	-	
N ₂	½	½	-	
N ₃	½	-	½	
N ₄	½	¼	¼	
N ₅	1/3	1/3	1/3	
N ₆	¼	½	¼	

SEd 0.02 0.06 0.24 0.16

CD(P=0.05) 0.04 0.13 0.48 NS

WAS - Weeks after sowing

DAS - Days after sowing

harvest stage, N₅ was significantly superior than N₁ producing 29.3 per cent higher CGR followed by N₄, while the least CGR value was recorded by N₁.

In 1998, at 30 to 50 DAS, N₂ exhibited superiority than N₃ with 11.6 per cent higher CGR values followed by N₆ and N₄. At 50 DAS to harvest stage, there existed no significant difference in CGR among various N split application treatments.

4.2.3. Relative growth rate (RGR)

The mean data on relative growth rate at 30 to 50 DAS and 50 DAS to harvest stages are presented in Table 10.

Plant population levels significantly influenced the relative growth rate during the crop growth in 1997. At 30 to 50 DAS, P₂ (30 x 30 cm) was found to increase the RGR but it was comparable with P₁ (30 x 37.5 cm) and P₃ (30 x 25 cm). At 50 DAS to harvest stages, P₁ was significantly superior than P₂ recording 11.8 per cent higher RGR and was comparable with P₃. In 1998, at both the stages of crop growth, the population level did not show any significant difference on RGR.

The RGR at 30 to 50 DAS did not vary significantly due to split application of N during 1997. At 50 DAS to harvest stages, N₄ treatment proved significantly superior than N₃ with 12.5 per cent increased RGR values and was comparable with N₅, N₆ and N₃ treatments. In 1998, at 30 to 50 DAS, N₆ was found to be significantly superior over N₃ with 5 per cent increased RGR values and was at par with N₂. At 50 DAS to harvest stages, different split applications of nitrogen did not show any significant change on RGR.

Table 10. Effect of plant population and split application of N on RGR ($\text{mg gm}^{-1} \text{day}^{-1}$)

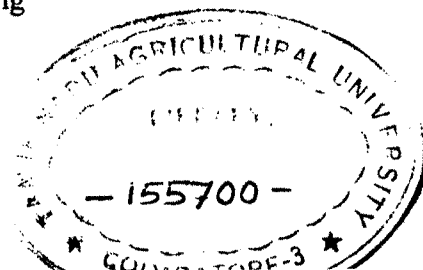
Treatments	NEM - 1997		NEM - 1998	
	30-50 DAS	50DAS - Harvest	30-50 DAS	50DAS - Harvest
Plant spacing				
P ₁ :30 x 37.5 cm	0.0814	0.0208	0.0868	0.0172
P ₂ :30 x 30cm	0.0829	0.0186	0.0873	0.0170
P ₃ :30 x 25cm	0.0789	0.0204	0.0875	0.0170
SEd	0.0027	0.0002	0.0002	0.0001
CD (P=0.05)	0.0075	0.0006	NS	NS
Split application of N				
	Basal	4 th WAS	6 th WAS	
N ₁	Full	-	-	0.0812
N ₂	½	½	-	0.0826
N ₃	½	-	½	0.0747
N ₄	½	¼	¼	0.0823
N ₅	1/3	1/3	1/3	0.0829
N ₆	¼	½	¼	0.0829

SEd 0.0039 0.0005 0.0005 0.0003

CD(P=0.05) NS 0.0010 0.0010 NS

WAS - Weeks after sowing

DAS - Days after sowing



4.2.4. Net assimilation rate (NAR)

The mean data on net assimilation rate recorded at 30 to 50 DAS and 50 DAS to harvest stages are presented in Table 11.

In 1997, at first stage, population levels did not show any significant difference on NAR. But at 50 DAS to harvest stages, P₃ (30 x 25 cm) was found to be significantly superior than P₁ (30 x 37.5 cm) producing about 25.4 per cent higher NAR, and was on par with P₂ (30 x 30 cm).

In 1998, at 30 to 50 DAS, P₃ treatment was superior than P₁ recording 17.3 per cent higher NAR while at 50 DAS to harvest stages, population levels did not show any significant change on NAR.

In 1997, split application of nitrogen at 30 to 50 DAS did not show any significant change on NAR. While at 50 DAS to harvest stage, N₄ produced 10.2 per cent of increased NAR than N₁ and was at par with N₃, N₅ and N₆ treatments.

In 1998 at 30 to 50 DAS, N₁ treatment proved significantly superior than N₅ indicating 28.9 per cent increased NAR and was comparable with N₂, N₆ and N₃. At 50 DAS to harvest stages, N split levels did not show any significant influence on NAR.

4.3. Days to 50 per cent flowering

The mean data on number of days to 50 per cent flowering are presented in Table 12.

Plant population levels and nitrogen split applications did not exhibit any significant influence on number of days to 50 per cent flowering, but a marginal

Table 11. Effect of plant population and split application of N on NAR ($\text{cm}^2 \text{g}^{-1} \text{day}^{-1}$)

Treatments				NEM - 1997		NEM - 1998	
				30-50 DAS	50DAS - Harvest	30-50 DAS	50DAS - Harvest
Plant spacing							
P ₁ :30 x 37.5 cm				0.0458	0.0169	0.0554	0.0209
P ₂ :30 x 30cm				0.0430	0.0209	0.0611	0.0230
P ₃ :30 x 25cm				0.0488	0.0212	0.0650	0.0274
SEd				0.0016	0.0006	0.0003	0.0023
CD (P=0.05)				NS	0.0008	0.0008	NS
Split application of N							
	Basal	4 th WAS	6 th WAS				
N ₁	Full	-	-	0.0469	0.0186	0.0726	0.0128
N ₂	½	½	-	0.0461	0.0188	0.0601	0.0225
N ₃	½	-	½	0.0453	0.0204	0.0583	0.0220
N ₄	½	¼	¼	0.0450	0.0205	0.0563	0.0219
N ₅	1/3	1/3	1/3	0.0461	0.0200	0.0563	0.0275
N ₆	¼	½	¼	0.0457	0.0198	0.0595	0.0231

SEd 0.0014 0.0006 0.0011 0.0036

CD(P=0.05) NS 0.0011 0.0021 NS

WAS - Weeks after sowing

DAS - Days after sowing

Table 12. Effect of plant population and nitrogen split application on number of days to 50 per cent flowering of sunflower.

Treatments				NEM - 1997	NEM - 1998
				No.of days to 50% flowering	No.of days to 50% flowering
Plant spacing					
P ₁ :30 x 37.5 cm				52.00	49.26
P ₂ :30 x 30cm				51.66	49.26
P ₃ :30 x 25cm				51.61	49.20
	SEd			0.38	0.32
	CD (P=0.05)			NS	NS
Split application of N					
	Basal	4 th WAS	6 th WAS		
N ₁	Full	-	-	52.00	49.33
N ₂	½	½	-	51.44	48.66
N ₃	½	-	½	52.00	49.30
N ₄	½	¼	¼	51.55	49.26
N ₅	1/3	1/3	1/3	52.00	49.3
N ₆	¼	½	¼	51.55	49.21
	SEd			0.55	0.53
	CD(P=0.05)			NS	NS

WAS - Weeks after sowing

DAS - Days after sowing

difference was noticed between the years. The number of days taken for 50 per cent flowering was comparably less in 1997 than in 1998.

4.4. Yield components

The mean data on yield components of sunflower recorded at maturity stage are presented in Table 13 and 14.

4.4.1. Head diameter

Plant population level significantly influenced the head diameter in both the years. In general, lower plant population of P₁ (30 x 37.5 cm) produced more head diameter than higher plant population. In 1997, 11 per cent increase in head diameter was noticed under P₁ treatment over P₃ (30 x 25 cm). In 1998 also P₁ treatment recorded increased head diameter by 16.4 per cent over P₃ treatment.

Split application of nitrogen also exerted significant difference in head diameter of sunflower in both the years. In 1997, N application through three splits (N₄) was found to be significantly superior over N₁ recording about 11.7 per cent increased head diameter and was on par with N₆ and N₅ treatment. In 1998, N application through two splits (N₂) recorded 18.7 per cent higher head diameter than N₃ treatment and was on par with N₆ treatment.

4.4.2. Total number of seeds

Total number of seeds head⁻¹ were maximum in wider spacing level of P₁ (30 x 37.5 cm) than closer spacing of P₃ (30 x 25 cm) in both the years. In 1997, significant increase in total number of seeds per head was noticed under P₁ treatment which produced 14.1 per cent more seeds than P₃. In 1998 also, P₁ treatment exhibited its superiority by producing 11.1 per cent higher number of seeds head⁻¹ than P₃ was at par with P₂.

Table 13. Effect of plant population and nitrogen split application on yield attributes of sunflower.

Treatments	NEM - 1997		NEM - 1998				
	Diameter of head(cm)	Total No. of seeds head ⁻¹	Diameter of head (cm)	Total No. of seeds head ⁻¹			
Plant spacing							
P ₁ :30 x 37.5 cm	12.38	509.11	13.62	648.85			
P ₂ :30 x 30cm	11.52	473.22	12.52	651.74			
P ₃ :30 x 25cm	11.15	446.05	11.70	583.81			
SEd	0.14	15.36	0.06	4.83			
CD (P=0.05)	0.38	42.65	0.17	13.43			
Split application of N							
	Basal	4 th WAS	6 th WAS				
N ₁	Full	-	-	11.01	451.33	12.66	625.93
N ₂	½	½	-	11.33	476.22	13.71	657.46
N ₃	½	-	½	11.23	455.22	11.55	599.71
N ₄	½	¼	¼	12.30	501.11	11.97	625.33
N ₅	1/3	1/3	1/3	12.09	499.22	12.45	615.77
N ₆	¼	½	¼	12.15	473.56	13.34	644.58
	SEd			0.14	16.66	0.21	6.03
	CD(P=0.05)			0.27	34.02	0.42	12.31
	WAS	-	Weeks after sowing				
	DAS	-	Days after sowing				

In general, split application of nitrogen significantly influenced the total number of seeds head⁻¹ in both the years. In 1997, significant increase in total number of seeds per head was recorded under N₄ which was superior than N₁ with 11 per cent more values and was at par with N₅, N₂ and N₆ treatments. In 1998, higher number of seeds head⁻¹ was recorded by N₂ treatment to about 9.7 per cent more than N₃ which recorded the least number of seeds head⁻¹.

4.4.3. Filling percentage

In 1997 and 1998, P₁ (30 x 37.5 cm) was found to be significantly superior in increasing the grain filling percentage than P₃ (30 x 25 cm) indicating an increase of 6.1 and 18.2 per cent, respectively. In both the years, the least grain filling percentage was noticed under P₃ treatment.

Split application of nitrogen also altered seed filling percentage significantly in both the years. In 1997, N₄ ($\frac{1}{2}$ N basal + $\frac{1}{4}$ on 4th week after sowing + $\frac{1}{4}$ on 6th week after sowing with rain) treatment was found to be significantly superior than N₁ treatment, but was at par with N₂, N₅ and N₆ treatments. In 1998, N₂ treatment significantly increased seed filling percentage to about 9.1 per cent more than N₃.

4.4.4. 100 seed weight

In 1997, plant population level did not exert any significant influence on 100 seed weight of the crop, whereas in 1998, 100 seed weight was significantly higher under P₁ (30 x 37.5 cm) than P₃ (30 x 25 cm) treatment by recording 14.7 per cent higher values.

Split application of nitrogen also influenced significantly the 100 seed weight. In 1997, significant increase in 100 seed weight was noticed under

Table 14. Effect of plant population and nitrogen split application on yield attributes of sunflower

Treatments				NEM - 1997		NEM - 1998	
				Filling percentage	100 seed weight (gm)	Filling percentage	100 seed weight (gm)
Plant spacing							
P ₁ :30 x 37.5 cm				84.21	4.50	91.23	5.83
P ₂ :30 x 30cm				82.25	4.45	85.61	5.59
P ₃ :30 x 25cm				79.36	4.43	77.40	5.08
SEd				0.37	0.03	0.21	0.05
CD (P=0.05)				1.03	NS	0.59	0.15
Split application of N							
	Basal	4 th WAS	6 th WAS				
N ₁	Full	-	-	81.26	4.32	85.15	5.56
N ₂	½	½	-	82.47	4.44	88.27	5.88
N ₃	½	-	½	80.98	4.52	80.94	5.02
N ₄	½	¼	¼	82.73	4.56	84.23	5.44
N ₅	1/3	1/3	1/3	82.47	4.40	83.21	5.40
N ₆	¼	½	¼	81.72	4.52	86.67	5.72

SEd 0.58 0.02 0.14 0.05

CD(P=0.05) 1.19 0.05 0.29 0.11

WAS - Weeks after sowing

DAS - Days after sowing

N_4 treatment which recorded 5.5 per cent more 100 seed weight than N_1 treatment. But the 100 seed weight under N_4 was at par with N_6 and N_3 treatments. In 1998, N_2 treatment recorded 17.1 per cent more 100 seed weight than N_3 , which recorded the least 100 seed weight.

4.5. Yield

The mean seed yield data of sunflower for both the 1997 and 1998 are presented in Table 15 (Fig. 9).

Population levels significantly altered the grain yield in both the years. In 1977, higher plant population level of P_3 (30 x 25 cm) produced 9.3 per cent more seed yield than P_1 (30 x 37.5 cm), while P_2 (30 x 30 cm) was at par with P_1 .

In 1998, lower plant population of P_1 (30 x 37.5 cm) produced 21.9 per cent higher yield than P_3 . Each plant population levels were independently superior over others with regard to grain yield.

Split application of nitrogen also had significant effect on seed yield of sunflower in both the years. In 1997, split application of nitrogen at N_4 ($\frac{1}{2}$ basal + $\frac{1}{4}$ on 4th week after sowing + $\frac{1}{4}$ on 6th week after sowing with rain) found significantly superior than N_1 (full basal) with 1.2 per cent more seed yield and was comparable with N_6 ($\frac{1}{4}$ basal + $\frac{1}{2}$ on 4th week after sowing + $\frac{1}{4}$ on 6th week after sowing with rain), while N_6 was at par with N_5 ($\frac{1}{3}$ basal + $\frac{1}{3}$ on 4th week after sowing + $\frac{1}{3}$ on 6th week after sowing with rain) and N_2 ($\frac{1}{2}$ basal + $\frac{1}{2}$ on 4th week after sowing with rain). In 1998, N_2 ($\frac{1}{2}$ basal + $\frac{1}{2}$ on 4th week after sowing with rain) was found to be superior by 13 per cent than N_3 ($\frac{1}{2}$ basal + $\frac{1}{2}$ on 6th week after sowing with rain), and all the treatments were independently significant to each other.

Table 15. Effect of plant population and split application of nitrogen on seed yield (kg ha^{-1}) of sunflower

Treatments	Plant spacing										
	NEM 1997					NEM 1998					
	P ₁	P ₂	P ₃	Mean	P ₁	P ₂	P ₃	Mean			
Split application of N											
N ₁	700	729	761	730	1029	938	847	938	938		
N ₂	736	748	801	762	1097	988	911	998			
N ₃	725	733	780	746	952	921	775	883			
N ₄	780	796	859	812	1008	964	824	932			
N ₅	741	761	821	774	987	945	802	911			
N ₆	761	776	840	792	1058	964	869	964			
Mean	741	757	810	-	1022	953	838	-			

P	SEd	8	CD (P=0.05)	24	SEd	4	CD (P=0.05)	11
N	21	42	NS	6	11	13	23	22
P at N	36	NS	NS	11	11	23	22	
N at P	34	NS	NS	11	11	23	22	

Table 16. Effect of plant population and split application of nitrogen on stalk yield (kg ha^{-1}) of sunflower

Treatments	Plant spacing											
	NEM 1997					NEM 1998						
	P ₁	P ₂	P ₃	Mean	P ₁	P ₂	P ₃	Mean				
Split application of N												
N ₁	3486	3617	4264	3789	3655	3913	4712	4094				
N ₂	3660	4106	4991	4252	3877	4083	4987	4315				
N ₃	4175	4309	5075	4520	3132	3326	4104	3520				
N ₄	3971	4335	5183	4480	3225	3808	4581	3871				
N ₅	4501	4432	5132	4688	3475	3666	4337	3826				
N ₆	4584	4502	5185	4757	3779	4013	4797	4196				
Mean	4063	4217	4963	-	3524	3802	4587	-				

	SEd	CD (P=0.05)	SEd	CD (P=0.05)
P	80	223	47	130
N	79	162	71	144
P at N	137	NS	121	NS
N at P	149	NS	122	NS

The interaction effect of plant population and nitrogen split application on seed yield was not significant in 1997, whereas in 1998, P_1N_2 (88,888 plants ha^{-1} at $\frac{1}{2}$ N basal + $\frac{1}{2}$ on 4th week after sowing with rain) combination found to give significantly higher seed yield than P_3N_3 (1,33,333 plants ha^{-1} at $\frac{1}{2}$ N basal + $\frac{1}{2}$ on 6th week after sowing with rain). Under N at P level, $N_2 P_1$ showed higher seed yield than $N_2 P_3$ ($\frac{1}{2}$ N basal + $\frac{1}{2}$ on 4th week after sowing with rain at 1,33,333 plants ha^{-1}) and N_2P_2 levels ($\frac{1}{2}$ N basal + $\frac{1}{2}$ on 4th week after sowing with rain at 1,11,111 plants ha^{-1}).

4.6. Stalk yield

The mean data on stalk yield are presented in Table 16.

The closer plant spacing of P_1 (30 x 25 cm) produced more stalk yield than wider spacing P_3 (30 x 37.5 cm) in both the years. In 1997, P_3 produced 18.2 per cent greater stalk yield than P_1 while P_2 (30 x 30 cm) treatment was comparable with P_1 . In 1998, P_3 had 23.2 per cent more stalk yield than P_1 and each treatment was individually significant from others.

In 1997, among the N split applications, N_6 ($\frac{1}{4}$ basal + $\frac{1}{2}$ on 4th week after sowing + $\frac{1}{4}$ on 6th week after sowing with rain) had 25.5 per cent more stalk yield than N_1 and also comparable with N_5 . Whereas in 1998, N_2 was superior than N_3 with 22.6 per cent higher stalk yield and was comparable with N_6 .

4.7. Quality characters

4.7.1. Oil content and oil yield

The mean data on oil content and oil yield are presented in Table 17.

The oil content was not significantly different with respect to plant spacing and nitrogen split application treatments in both the years. The oil yield was

Table 17. Effect of plant population and nitrogen split application on crude protein (%), oil content (%) and oil yield (kg ha⁻¹) of sunflower.

Treatments				NEM - 1997			NEM - 1998		
				Protein content (%)	Oil content (%)	Oil yield (kg/ha ⁻¹)	Protein content (%)	Oil content (%)	Oil yield (kg/ha ⁻¹)
Plant spacing									
P ₁ :30 x 37.5 cm				17.67	37.05	274.5	18.53	36.70	374.7
P ₂ :30 x 30cm				17.63	37.17	281.4	18.52	36.74	349.8
P ₃ :30 x 25cm				17.62	37.18	301.2	18.47	36.79	305.8
SEd				0.21	0.09	5.4	0.11	0.07	16.3
CD (P=0.05)				NS	NS	14.8	0.23	NS	43.9
Split application of N									
	Basal	4 th WAS	6 th WAS						
N ₁	Full	-	-	17.03	37.23	271.8	18.35	36.8	345.0
N ₂	½	½	-	17.25	37.13	282.9	18.79	36.2	361.0
N ₃	½	-	½	17.34	37.12	276.9	18.07	37.5	331.0
N ₄	½	¼	¼	18.36	37.01	301.0	18.57	36.2	337.5
N ₅	1/3	1/3	1/3	17.08	37.20	288.1	18.29	37.2	338.9
N ₆	¼	½	¼	18.07	37.10	293.8	18.96	36.1	347.7

SEd 0.11 0.16 11.0 0.02 0.90 8.3

CD(P=0.05) 0.22 NS 22.1 0.04 NS 16.8

WAS - Weeks after sowing

DAS - Days after sowing

maximum at higher plant population levels than at lower plant populations in both the years. In 1997, P₃ (30 x 25 cm) treatment produced 9.7 per cent more oil yield than P₁ (30 x 37.5 cm) whereas in 1998, P₁ treatment produced 22.5 per cent higher oil yield than P₃ treatment.

Regarding split application of nitrogen, in 1997, N₄ treatment recorded 10.7 per cent higher oil yield than N₁ treatment. Whereas in 1998, N₂ treatment produced more oil yield which was 9.1 per cent higher than N₃.

4.7.2. Crude protein content

The influence of treatments on crude protein content of sunflower are presented in Table 17.

In 1997, plant population levels did not influence the protein content of sunflower significantly. Whereas in 1998, lower plant population level (30 x 37.5 cm) of P₁ produced more protein content and it was comparable with P₂ (30 x 30 cm).

In 1997, application of N at three splits ($\frac{1}{2}$ basal + $\frac{1}{4}$ on 4th week after sowing + $\frac{1}{4}$ on 6th week after sowing with rain) was superior with 7.8 per cent protein content than N₁. During 1998, N₃ had 4.9 per cent more protein content than N₆ and each of the treatments were individually significant.

4.8. Nutrient uptake

4.8.1. Nitrogen uptake

The mean data on nitrogen uptake are presented in Table 18 (Fig. 10 and 11).

Table 18. Effect of plant population and N split application on nitrogen uptake (kg ha^{-1}) of sunflower

Treatments				NEM - 1997			NEM - 1998		
				30DAS	50DAS	Harvest	30DAS	50DAS	Harvest
Plant spacing									
P ₁ :30 x 37.5 cm				21.28	39.43	68.66	22.09	35.56	72.33
P ₂ :30 x 30cm				24.37	40.30	71.49	22.8	38.36	73.28
P ₃ :30 x 25cm				25.03	43.09	76.17	23.6	41.91	75.77
SEd				0.26	0.24	0.39	0.25	0.26	0.31
CD (P=0.05)				0.55	0.66	1.09	0.68	0.72	0.87
Split application of N									
	Basal	4th WAS	6th WAS						
N ₁	Full	-	-	24.09	36.86	64.17	24.11	40.03	74.10
N ₂	½	½	-	23.21	41.30	71.12	22.97	42.01	75.65
N ₃	½	-	½	23.53	39.95	71.40	22.74	38.23	72.33
N ₄	½	¼	¼	23.57	40.96	75.01	22.69	39.53	72.97
N ₅	1/3	1/3	1/3	23.75	42.69	75.47	22.35	39.00	73.05
N ₆	¼	½	¼	23.18	43.89	75.50	22.16	40.89	74.68

SEd 0.36 0.25 0.46 0.19 0.39 0.29

CD(P=0.05) NS 0.52 0.94 0.39 0.80 0.60

WAS - Weeks after sowing

DAS - Days after sowing

At higher plant population level, nitrogen uptake were maximum, though the uptake by individual plants was less. In 1997 and 1998 at 30 DAS, N uptake in P₃ (30 x 25 cm) treatment was 17.6 and 6.8 per cent more than P₁ (30 x 37.5 cm) respectively, and each of treatments were individually significant.

The nitrogen uptake at 50 DAS were greater by 9.3 per cent in P₃ than P₁ during 1997. The corresponding increase in 1998 was 17.8 per cent.

In 1997 and 1998 at harvest stage, nitrogen uptake were maximum in P₃ treatment which recorded 10.9 and 4.9 per cent higher uptake than P₁ respectively.

In 1997, at 30 DAS, split application of N on nitrogen uptake was not significant. At 50 DAS, among the N split application treatments, N₆ was significantly superior than N₁ with 19.1 per cent higher values. At harvest stage, application of three splits ($\frac{1}{4}$ N basal + $\frac{1}{2}$ on 4th week after sowing + $\frac{1}{4}$ on 6th week after sowing) recorded 17.6 per cent higher N uptake than full basal application.

In 1998, at 30 DAS, N uptake was maximum in N₁ treatment which recorded 8.8 per cent higher values than N₆. At 50 DAS, N₂ treatment recorded 9.9 per cent higher nitrogen uptake than N₃. At harvest stage N₂ was superior than N₃ by 4.6 per cent and each treatment showed individual significance, however N₆ was on par with N₁.

4.8.2. Phosphorus uptake

The mean data on phosphorus uptake are presented in Table 19.

In 1997 and 1998, P uptake at 30 DAS was maximum in P₃ (30 x 25 cm) than at P₁ (30 x 30 cm) with 11.1 and 4.8 per cent higher values respectively. The

Table 19. Effect of plant population and N split application on phosphorus uptake (kg ha^{-1}) of sunflower.

Treatments	NEM - 1997			NEM - 1998					
	30DAS	50DAS	Harvest	30DAS	50DAS	Harvest			
Plant spacing									
P ₁ :30 x 37.5 cm	1.530	5.65	11.690	1.830	6.24	11.42			
P ₂ :30 x 30cm	1.640	6.21	11.930	1.850	6.39	11.61			
P ₃ :30 x 25cm	1.700	6.38	12.990	1.920	6.63	11.99			
SEd	0.001	0.01	0.030	0.003	0.014	0.03			
CD (P=0.05)	0.003	0.03	0.080	0.018	0.038	0.09			
Split application of N									
	Basal	4 th WAS	6 th WAS						
N ₁	Full	-	-	1.630	5.98	11.030	1.920	6.39	11.72
N ₂	½	½	-	1.620	6.12	12.130	1.880	6.74	11.99
N ₃	½	-	½	1.620	5.96	12.230	1,860	6.16	11.38
N ₄	½	¼	¼	1.620	6.10	12.520	1.870	6.37	11.59
N ₅	1/3	1/3	1/3	1.620	6.16	12.710	1.840	6.32	11.55
N ₆	¼	½	¼	1.620	6.17	12.600	1.820	6.54	11.82

SEd 0.006 0.008 0.035 0.007 0.07 0.05

CD(P=0.05) NS 0.016 0.072 0.015 0.15 0.10

WAS - Weeks after sowing

DAS - Days after sowing

P uptake at 50 DAS were greater by 12.9 per cent in P₃ than P₁ during 1997. The corresponding increase in 1998 was only 6.3 per cent.

In 1997, at harvest stage, P uptake was significantly higher in P₃ treatment with 11.1 per cent higher values than P₁. In 1998 also P₃ population level had maximum uptake than P₁ and the increase more by 4.9 per cent.

In 1997, split application of N on P uptake at 30 DAS was not significant. At 50 DAS, among the N split application treatments, P uptake was more in N₆ than N₃ and was at par with N₅. At harvest stage, maximum P uptake was noticed in N₅ treatment which was 15.2 per cent higher than N₁ and it was on par with N₆.

In 1998, at 30 DAS, P uptake was maximum in N₁ treatment which produced 5.5 per cent higher uptake than N₆. At 50 DAS, N₂ treatment recorded 9.4 per cent higher P uptake than N₃. At harvest stage, P uptake was maximum in N₂ treatment, which was 5.4 per cent higher than N₃ treatment.

4.8.3. Potassium uptake

The mean data on potassium uptake are presented in Table 20.

In 1997 and 1998, uptake of K at 30 DAS was significantly superior in P₃ (30 x 25 cm) than P₁ (30 x 37.5 cm) with 14.1 and 4.8 per cent higher uptake values respectively. In 1997, at 50 DAS, K uptake were greater by 13.1 per cent in P₃ than P₁. The corresponding increase in 1998 was 6.2 per cent.

At harvest stage, K uptake was maximum in P₃ treatment with 10.8 per cent higher values than P₁ and the difference was significant during 1997. In 1998 also P₃ population level had maximum K uptake than P₁.

Table 20. Effect of plant population and N split application on potassium uptake (kg ha^{-1}) of sunflower

Treatments				NEM - 1997			NEM - 1998		
				30DAS	50DAS	Harvest	30DAS	50DAS	Harvest
Plant spacing									
P ₁ :30 x 37.5 cm				8.51	47.70	99.14	10.99	52.02	95.14
P ₂ :30 x 30cm				9.54	52.60	100.81	11.15	53.25	96.62
P ₃ :30 x 25cm				9.71	53.96	109.89	11.52	55.27	100.14
SEd				0.16	0.25	0.20	0.03	0.11	0.23
CD (P=0.05)				0.44	0.69	0.56	0.09	0.31	0.63
Split application of N									
	Basal	4 th WAS	6 th WAS						
N ₁	Full	-	-	9.19	50.47	93.36	11.56	53.27	97.63
N ₂	½	½	-	9.08	51.69	102.49	11.30	56.17	99.45
N ₃	½	-	½	9.30	50.30	103.58	11.22	51.29	94.90
N ₄	½	¼	¼	9.21	51.63	106.35	11.24	53.10	96.59
N ₅	1/3	1/3	1/3	9.38	51.15	107.47	11.07	52.67	96.24
N ₆	¼	½	¼	9.37	52.29	106.41	10.97	54.59	98.5

SEd 0.17 0.16 0.34 0.04 0.60 0.45

CD(P=0.05) NS 0.33 0.70 0.08 1.23 0.92

WAS - Weeks after sowing

DAS - Days after sowing

In 1997, at 30 DAS, split application of N on K uptake was not significant. At 50 DAS, among the N split application treatments, K uptake was more in N₆ than N₃. At harvest stage, K uptake was greater by 15.1 per cent in N₅ than N₁ treatment and the difference was significant, while N₆ was on par with N₄.

In 1998, at 30 DAS, K uptake were maximum in N₁ treatment with 5.4 per cent higher values than N₆. At 50 DAS, N₂ treatment recorded 9.5 per cent higher K uptake than N₃. At harvest stage, N₂ had 4.8 per cent higher uptake than N₃ and was on par with N₆.

4.9. Post harvest Soil available nutrient

The mean data on post harvest soil available nitrogen are presented in Table 21.

Soil available N, P and K status at post harvest was not influenced by population levels in both the years. Regarding N split application, soil available nitrogen was maximum in N₃ during 1997, which was 4.9 per cent higher than N₁ and was on par with N₅. The nitrogen split levels did not show any significant difference on available P and K in 1997 and available N, P and K in 1998.

4.10. Economics

The data on economics of various treatments are presented in Table 22 and 23 (Fig. 12 and 13).

The economics of various treatments were worked out based on income obtained from economic produce and cost of cultivation. In 1997, among the treatment combinations, P₃ N₄ (1,33,333 plants ha⁻¹ at ½ N basal + ¼ on 4th week after sowing + ¼ on 6th week after sowing with rain) gave the highest gross return (5100.2 Rs ha⁻¹), net return (1925.6 Rs ha⁻¹), B.C. ratio (1.60 Rs ha⁻¹) and per day

Table 21. Effect of plant population and N split application on post harvest soil available nutrient (kg ha^{-1})

Treatments				NEM - 1997			NEM - 1998		
				N	P	K	N	P	K
Plant spacing									
P ₁ :30 x 37.5 cm				158.96	8.41	368.1	153.96	8.31	363.3
P ₂ :30 x 30cm				157.88	8.39	366.3	153.1	8.24	361.8
P ₃ :30 x 25cm				156.28	8.31	363.9	151.94	8.22	359.7
SEd				1.18	0.57	2.17	0.81	0.10	2.04
CD (P=0.05)				NS	NS	NS	NS	NS	NS
Split application of N									
	Basal	4 th WAS	6 th WAS						
N ₁	Full	-	-	153.96	8.43	367.8	151.28	8.26	360.9
N ₂	½	½	-	155.71	8.30	366.7	152.27	8.32	361.7
N ₃	½	-	½	161.50	8.40	367.4	154.54	8.32	362.9
N ₄	½	¼	¼	157.24	8.36	365.2	153.50	8.21	359.8
N ₅	1/3	1/3	1/3	159.55	8.37	363.7	153.33	8.20	360.1
N ₆	¼	½	¼	158.30	8.41	363.25	153.07	8.29	362.4

SEd 1.27 0.59 2.21 1.51 0.11 2.06

CD(P=0.05) 2.59 NS NS NS NS NS

WAS - Weeks after sowing

DAS - Days after sowing

Table 22

Economics - NEM 1997

Treatments	Cost of cultivation (Rs. ha ⁻¹)	Gross return (Rs. ha ⁻¹)	Net return (Rs. ha ⁻¹)	B.C. ratio	Per day return (Rs. ha ⁻¹)
P ₁ N ₁	3070	4349	1280	1.42	14.7
P ₁ N ₂	3105	4521	1416	1.45	16.3
P ₁ N ₃	3105	4426	1322	1.43	15.2
P ₁ N ₄	3140	4704	1564	1.50	18.0
P ₁ N ₅	3140	4575	1435	1.46	16.5
P ₁ N ₆	3140	4621	1482	1.47	17.0
P ₂ N ₁	3084	4434	1350	1.44	15.5
P ₂ N ₂	3120	4615	1496	1.48	17.2
P ₂ N ₃	3120	4474	1355	1.43	15.6
P ₂ N ₄	3155	4775	1620	1.51	18.6
P ₂ N ₅	3155	4657	1503	1.48	17.3
P ₂ N ₆	3155	4675	1521	1.48	17.5
P ₃ N ₁	3104	4758	1654	1.53	19.0
P ₃ N ₂	3140	4913	1773	1.56	20.4
P ₃ N ₃	3140	4791	1651	1.52	19.0
P ₃ N ₄	3175	5100	1926	1.60	22.1
P ₃ N ₅	3175	4980	1805	1.57	20.7
P ₃ N ₆	3175	5015	1840	1.60	21.1

Table 23

Economics - NEM 1998

Treatments	Cost of cultivation (Rs. ha ⁻¹)	Gross return (Rs. ha ⁻¹)	Net return (Rs. ha ⁻¹)	B.C. ratio	Per day income (Rs. ha ⁻¹)
P ₁ N ₁	3102	6174	3073	1.99	35.3
P ₁ N ₂	3137	6583	3446	2.10	39.6
P ₁ N ₃	3137	5706	2570	1.82	29.5
P ₁ N ₄	3172	6047	2875	1.90	33.0
P ₁ N ₅	3172	5922	2751	1.87	31.6
P ₁ N ₆	3172	6348	3177	2.00	36.5
P ₂ N ₁	3115	5631	2516	1.81	28.9
P ₂ N ₂	3150	5929	2780	1.88	32.0
P ₂ N ₃	3150	5528	2378	1.76	27.3
P ₂ N ₄	3185	5784	2600	1.82	29.9
P ₂ N ₅	3185	5668	2484	1.78	28.5
P ₂ N ₆	3185	5781	2597	1.82	29.8
P ₃ N ₁	3130	5081	1951	1.62	22.4
P ₃ N ₂	3165	5457	2293	1.72	26.4
P ₃ N ₃	3165	4753	1488	1.50	17.1
P ₃ N ₄	3200	4946	1746	1.54	20.1
P ₃ N ₅	3200	4809	1610	1.50	18.5
P ₃ N ₆	3200	5213	2013	1.62	23.1

return (22.8 Rs ha⁻¹) than P₁ N₁ and was followed by P₃ N₆ (1,33,333 plants ha⁻¹ at ¼ N basal + ½ on 4th week after sowing with rain + ¼ on 6th week after sowing with rain).

In 1998, among the treatment combinations, P₁ N₂ (88,888 plants ha⁻¹ at ½ N basal + ½ on 4th week after sowing with rain) treatment gave highest gross return (Rs.6582.9 ha⁻¹), net return (Rs.3446.4 ha⁻¹), B.C. ratio (2.10) and per day income (Rs.39.6 ha⁻¹) than P₃N₃ (30 x 25 cm at ½ N basal + ½ on 6th week after sowing with rain) and was followed by P₁N₆ (88,888 plants ha⁻¹ at ½ N basal + ½ on 4th week after sowing with rain + ¼ on 6th week after sowing with rain).

4.11. Soil available moisture (Appendix III and IV)

Soil available moisture observations were recorded at 15 days interval in two depths (0-15cm and 15-30cm) during NEM 1997 and NEM 1998. In general, the treatments possessing lower plant population of 88,888 plants ha⁻¹ (P₁) showed more soil available moisture than the treatment with higher plant population (1,33,333 plants ha⁻¹). In NEM, 1997 and NEM, 1998, soil moisture at 30 cm depth level was found to be more than at 15cm depth at all the stages of crop growth. Split application of nitrogen did not show much difference on available soil moisture at all the crop growth stages.

✓

Discussion

CHAPTER V

DISCUSSION

Field experiments were conducted at Tamil Nadu Agricultural University Farm, Coimbatore during North East Monsoon (October-December) seasons of 1997 and 1998 to study the influence of plant population and split application of nitrogen on growth and yield of sunflower under rainfed vertisols. The results obtained from the experiments are discussed in this chapter.

5.1. Effect of plant population

5.1.1. Growth characters

The growth characters of sunflower studied in the present investigations are plant height, stem girth, leaf area index and dry matter production. Higher plant population level of 1,33,333 plants ha⁻¹ recorded significantly higher plant height irrespective of stages and years of study. This indicated that under crowded situation, individual plants tend to grow faster and taller for want of light. However, the stem girth of plants was lower in higher plant densities than the plants under lower population level of 88,888 plants ha⁻¹. Probably under rainfed condition, plants under higher population density extracted soil moisture quickly and thereby thinner and taller plants were produced (Dhoble *et al.*, 1988). Though the total dry matter production of individual plants were higher under low plant density, considering the population per unit area, the total dry matter production was higher at higher plant density. Total leaf area also tend to follow the same trend as that of total dry matter production recording lower values at low plant population levels and higher values at higher plant densities. Similar findings were also reported by Subba Reddy *et al.*, (1997).

Fig. 5. Effect of plant population and split application of nitrogen on dry matter production (Kg. ha^{-1}) - NEM, 1997

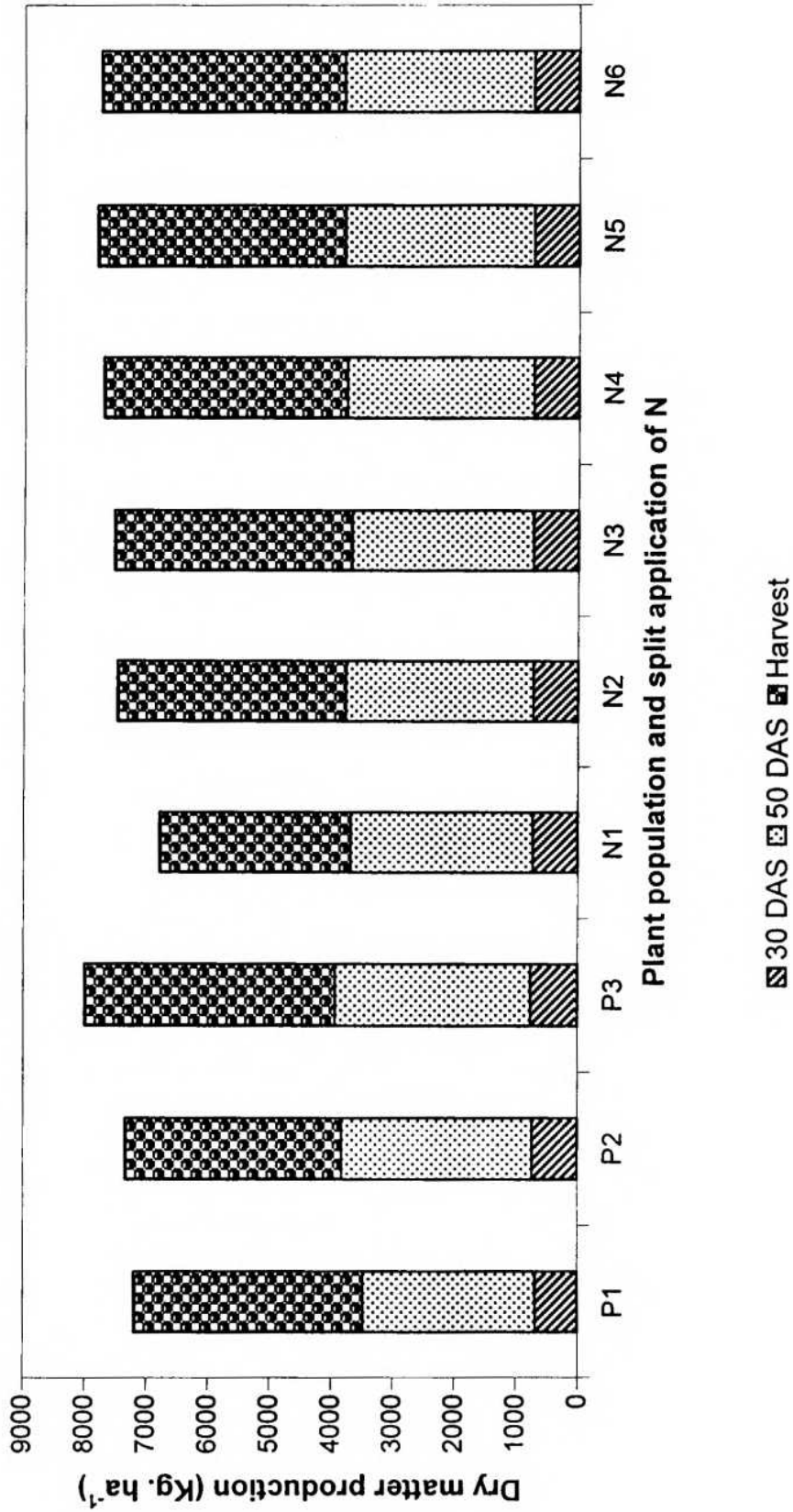
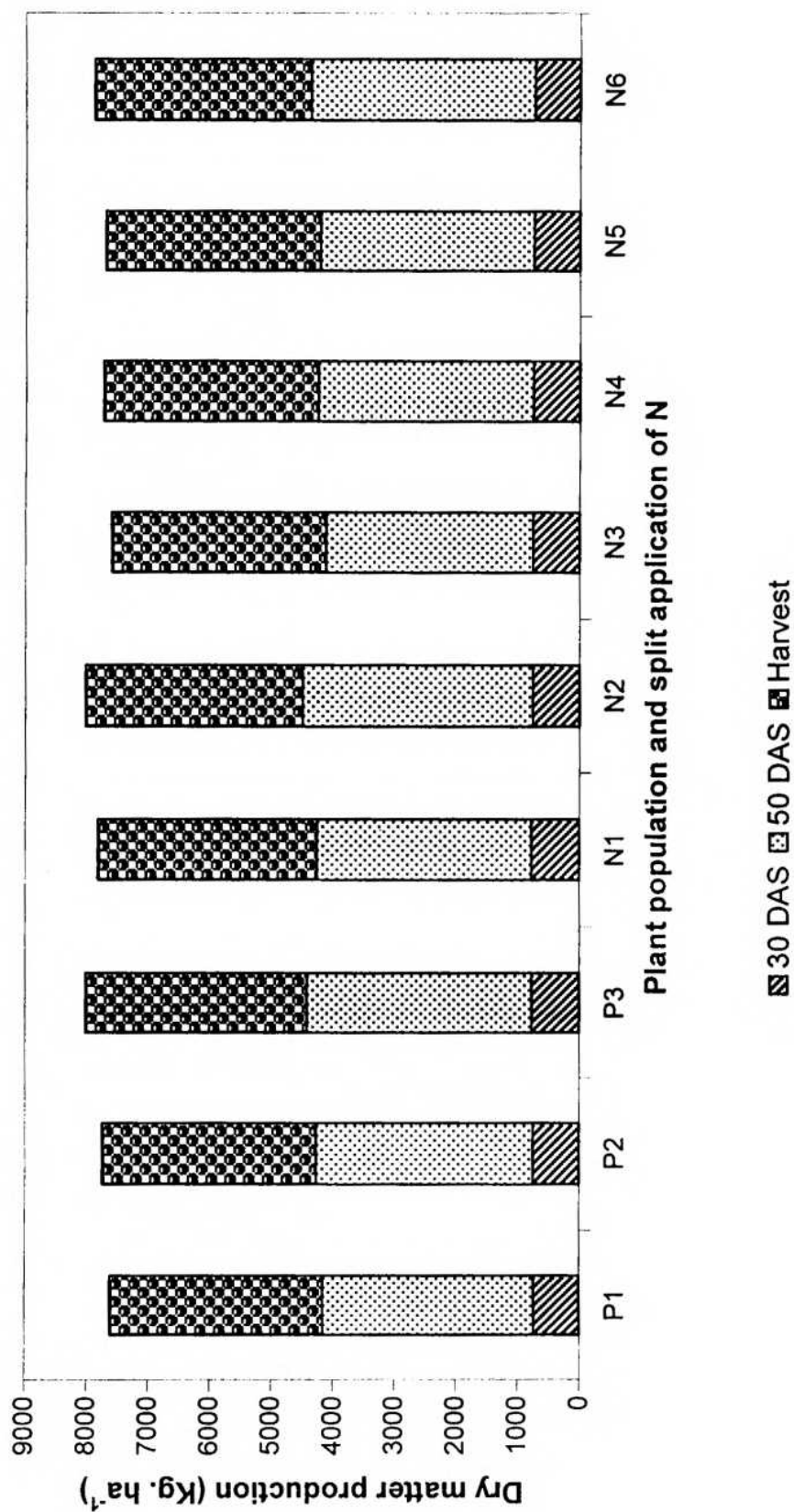


Fig. 6. Effect of plant population and split application of nitrogen on dry matter production (Kg. ha^{-1}) - NEM, 1998



Days to 50 per cent flowering was earlier under higher plant population of 1,33,333 plants ha⁻¹ because of more competition which induced quick growth and early flowering. Under lower plant density, at a spacing of 30 x 37.5 cm, the days to 50 per cent flowering was delayed marginally because of lesser competition for moisture and nutrients resulting in slower growth with more carbohydrate assimilation per plant (Holt and Campbell, 1984).

5.1.2. Growth analysis

Agronomic management practices like plant population could alter the growth analysis parameters like crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR). Among the plant population levels, higher plant density (1,33,333 plants ha⁻¹) at 30 x 25 cm spacing increased the crop growth rate and net assimilation rate in both the years because of more dry matter accumulation in unit area. The effect of plant population on relative growth rate was marginal irrespective of stages and years of study. This indicated that the relative assimilation per unit dry weight was similar irrespective of plant population levels (Nandhagopalan, 1997).

5.1.3. Yield attributes

The yield attributes recorded in the study are head diameter, total number of seeds head⁻¹, seed filling percentage and 100 seed weight. All the yield parameters were significantly superior under wider spacing (30 x 37.5 cm), because of less below and above ground competition among the plants. This type of variation were attributed to availability of more light and thereby higher light interception by the actively spreading and horizontally developed plant, which could reduce higher atmospheric CO₂ into food materials because of greater initial light use efficiency.

However higher plant population (1,33,333 plants ha⁻¹) at 30 x 25 cm spacing produced relatively low values of yield parameters. Reduction in the values of yield parameters due to severe competition among sunflower plants in closer spacing especially under rainfed situation where moisture is a major limiting factor throughout the crop growth period was also reported by Vijayalakshmi *et al.* (1975) and Shaik and Sagar (1983). Plant spacings of 30 x 37.5 cm and 30 x 30 cm were comparable with respect to total number of seeds head⁻¹ in both the years indicating the greater elasticity of sunflower with respect to plant populations (Kene *et al.*, 1992).

5.1.4. Yield

Sunflower seed yield was significantly influenced by various spacings tried in both the years of experimentation. Closer spacing of 30 x 25 cm (1,33,333 plants ha⁻¹) recorded significantly higher yield over wider spacing of 30 x 30 cm and 30 x 37.5 cm in 1997. Though the yield attributes were higher under wider plant spacing of 30 x 37.5 cm on per plant basis, due to more number of plants ha⁻¹ under closer spacing, the yield was higher on unit area basis. The per cent yield loss due to competition under higher density was compensated due to increased plant population per unit area. The increased seed yield of sunflower with higher plant density was also due to higher total dry matter and total leaf area produced at all the growth stages. Higher growth components at higher plant density were the result of better utilization of rainfall in favourable environment and effective moisture utilization during high rainfall years (Reddy and Gajendra Giri, 1997). Increased yield parameters at lower plant density could not be compensated with the yield obtained at higher plant density of 1,33,333 plants ha⁻¹ because of sub-optimal plant population in a well distributed high rain fall year.

During North East Monsoon season of 1998, increased yield parameters at lower plant density of 88,888 plants ha⁻¹ produced higher seed yield on per hectare basis. The spacing of 30 x 37.5 cm was significantly superior in producing higher seed yield when compared to closer spacing of 30 x 30 and 30 x 25 cm. This may possibly due to severe competition between the plants under closer spacing especially during the moisture stress, experienced in vegetative and early reproductive stages of the crop. Though the total rainfall received in the cropping period of 1998 (571 mm) was 78 per cent higher than the normal seasonal rainfall of 321 mm, the distribution is not uniform indicating higher intensity of rainfall with lesser number of rainy days. This situation has created greater soil moisture deficit under higher plant population levels because of greater competition between the plants. It was also evident from other studies on sunflower that increased plant population in relatively dry years can not compensate with the yields obtained at lower plant densities on per plant basis (Dhoble *et al.*, 1988). The suitability of sub-optimal plant population under moisture stress condition was also reported by Rao and Reddy (1985).

The straw yield was significantly higher under the closer spacing of 30 x 25 cm (1,33,333 plants ha⁻¹) when compared to other two plant population levels (1,11,111 plants ha⁻¹ and 88,888 plants ha⁻¹) irrespective of years of study. This may be due to higher dry matter accumulation under higher plant density in both favourable and unfavourable seasons. Eventhough the soil moisture stress at vegetative and early reproductive stages during 1998 restricted the synthesis of assimilates in storage organs (the capitulum), the total dry matter accumulated in the leaves and stem were not affected indicating flexibility of sunflower in dry matter allocation pattern. Similar results of increased stalk yield with higher plant density under rainfed situation were reported by Umrani and Bhoi (1985).

5.1.5. Quality characters

The wider spacing of 30 x 37.5 cm recorded significantly high protein content over 30 x 30 and 30 x 25 cm spacings during 1998. However, the effect was not significant during 1997 due to non limiting moisture availability throughout the crop growth period under lesser plant density behaved better than the plants under all population levels studied. But in 1998, plants under crowded situation due to intermitent dry spell. This inturn affected the most important quality parameter of oil content. The oil content in various spacing treatments did not differ much though slightly higher oil content was noticed with wider spacings. Higher protein and oil yield in wider spacing of 30 x 37.5 cm may be due to higher seed filing percentage and test weight which promoted accumulation of more protein and oil (Kene *et al.*, 1992).

5.1.6. Nutrient uptake

In general, the N, P and K uptake was influenced by the plant population levels irrespective of stages of crop growth and years of study. The population of 1,33,333 plants ha⁻¹ (30 x 25cm) invariably resulted in maximum N, P and K uptake followed by the population level of 1,11,111 plants ha⁻¹. The possible reason might be the greater dry matter production under high population density on per hectare basis. Similar results of increased NPK uptake with higher plant density was reported by Subba Reddy *et al.*, (1997).

5.2. Effect of N split application

5.2.1. Growth attributes

In general, split application of N at different growth stages produced higher

Fig. 7. Effect of plant population and N split application on leaf area index of sunflower - NEM, 1997

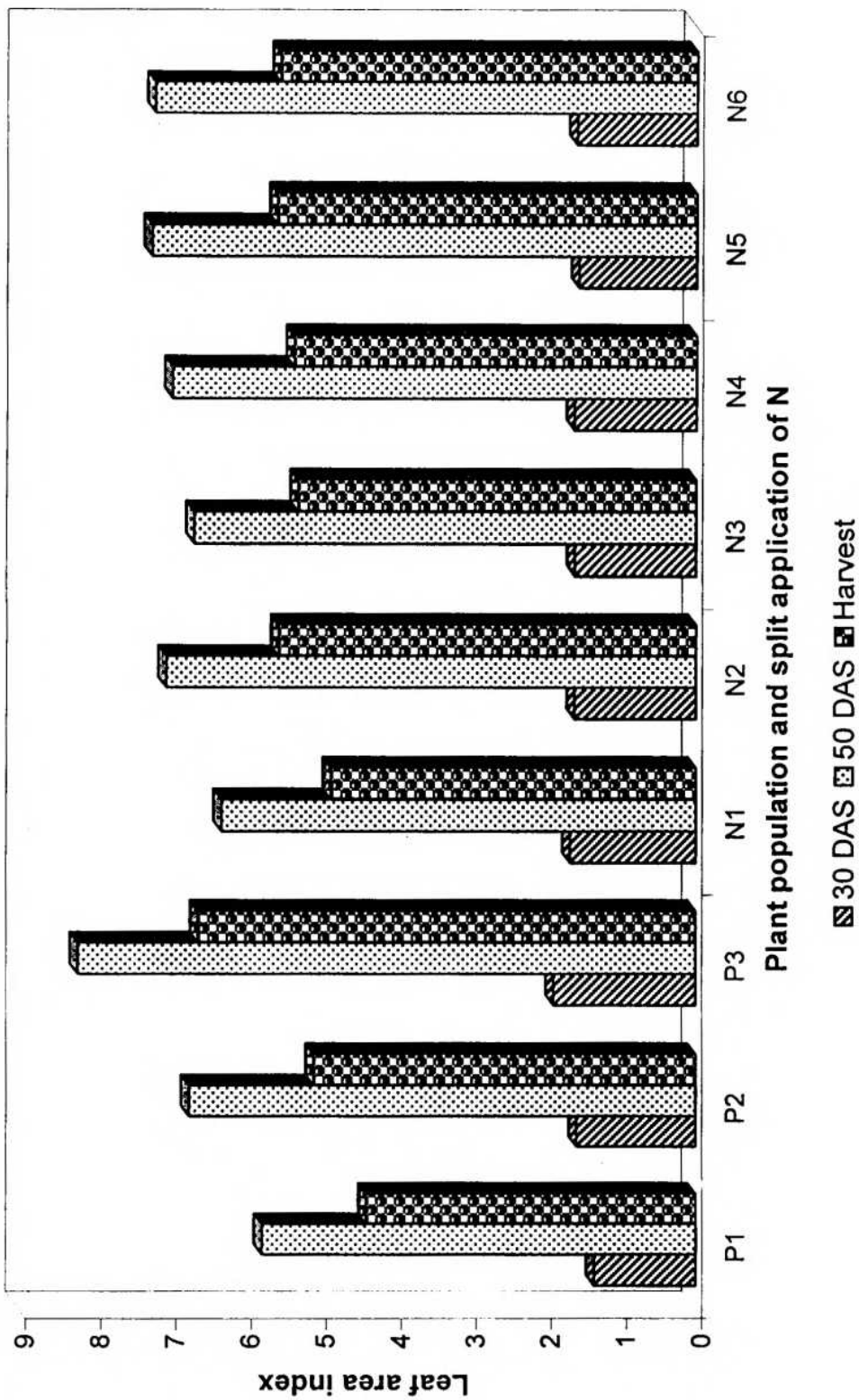
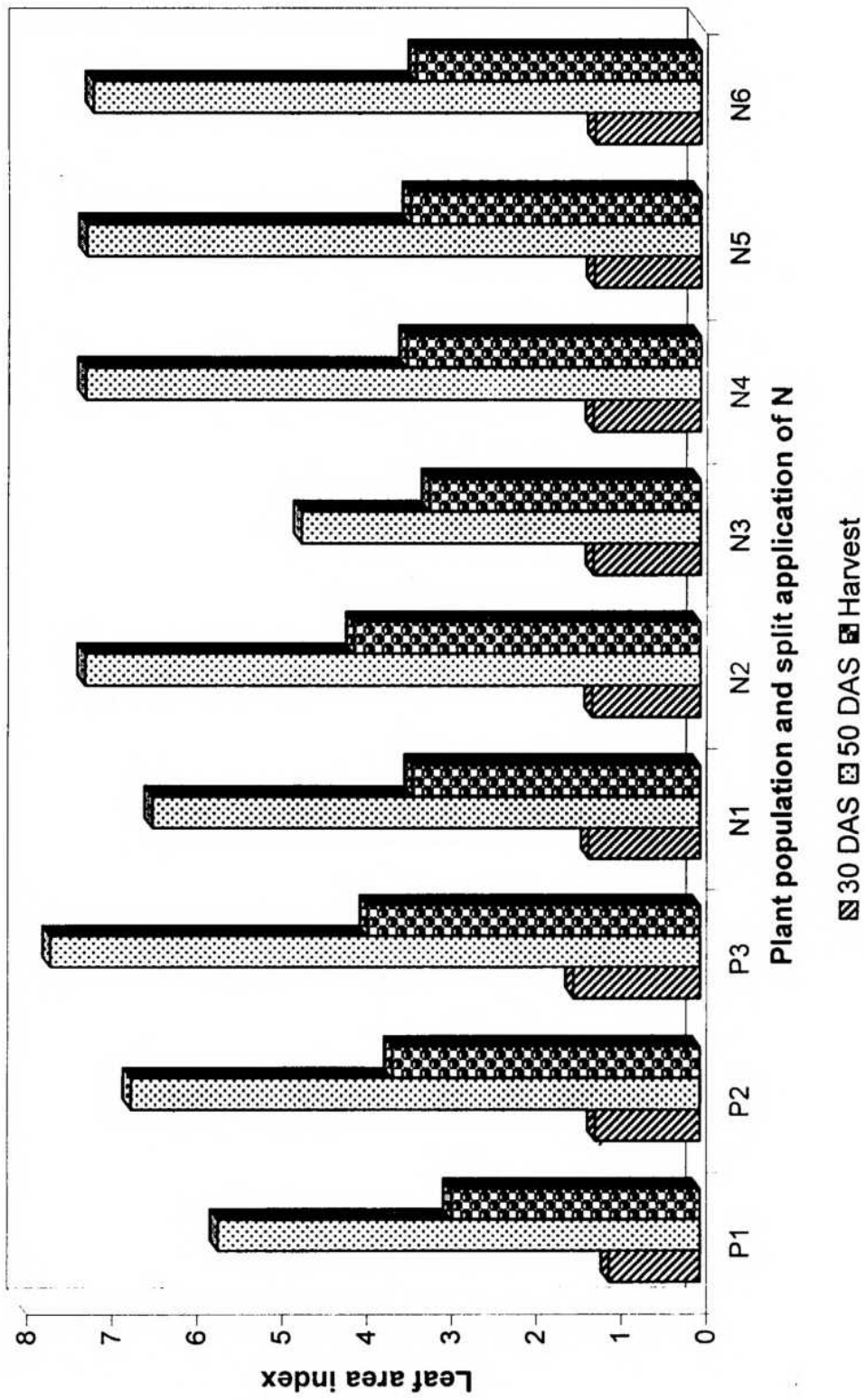


Fig. 8. Effect of plant population and N split application on leaf area index of sunflower - NEM, 1998



growth parameters in both the years compared to full basal application. Among the N split application treatments, application of N in two equal splits, the first at the time of sowing and the second on 4th week after sowing with receipt of rainfall had higher plant height, stem girth, LAI and DMP when compared to other N split application treatments. Continuous availability of N upto flowering stage might have resulted in better growth of sunflower with higher growth parameter values. This clearly indicated that the soil N availability before flowering under rainfed situation is very critical for uniform growth of sunflower plants. Application of N in three splits, the third after flowering did not produce any appreciable increase in the values of growth parameters because of lesser rate of uptake of nutrients after flowering.

5.2.2. Growth analysis

Split application of N caused significant change in crop growth rate (CGR) except during 50 DAS to harvest stage of 1998. Though the effect of nitrogen split application was significant with respect to relative growth rate (RGR) and net assimilation rate (NAR), the trend was not similar with the treatments. Such type of variation might be due to difference in rainfall pattern and soil moisture availability through the crop growth period. Similar findings were reported by Narasimha Rao and Narsa Reddy (1982). However, in general split application of nitrogen increased the growth analysis parameters (CGR, RGR and NAR). The growth rate of sunflower was boosted whenever adequate moisture and nitrogen was present in the soil at the important phenological stages of crop growth. This might be due to accumulation of more assimilate allocation in different plant parts (Reddy and Gajendra Giri, 1996).

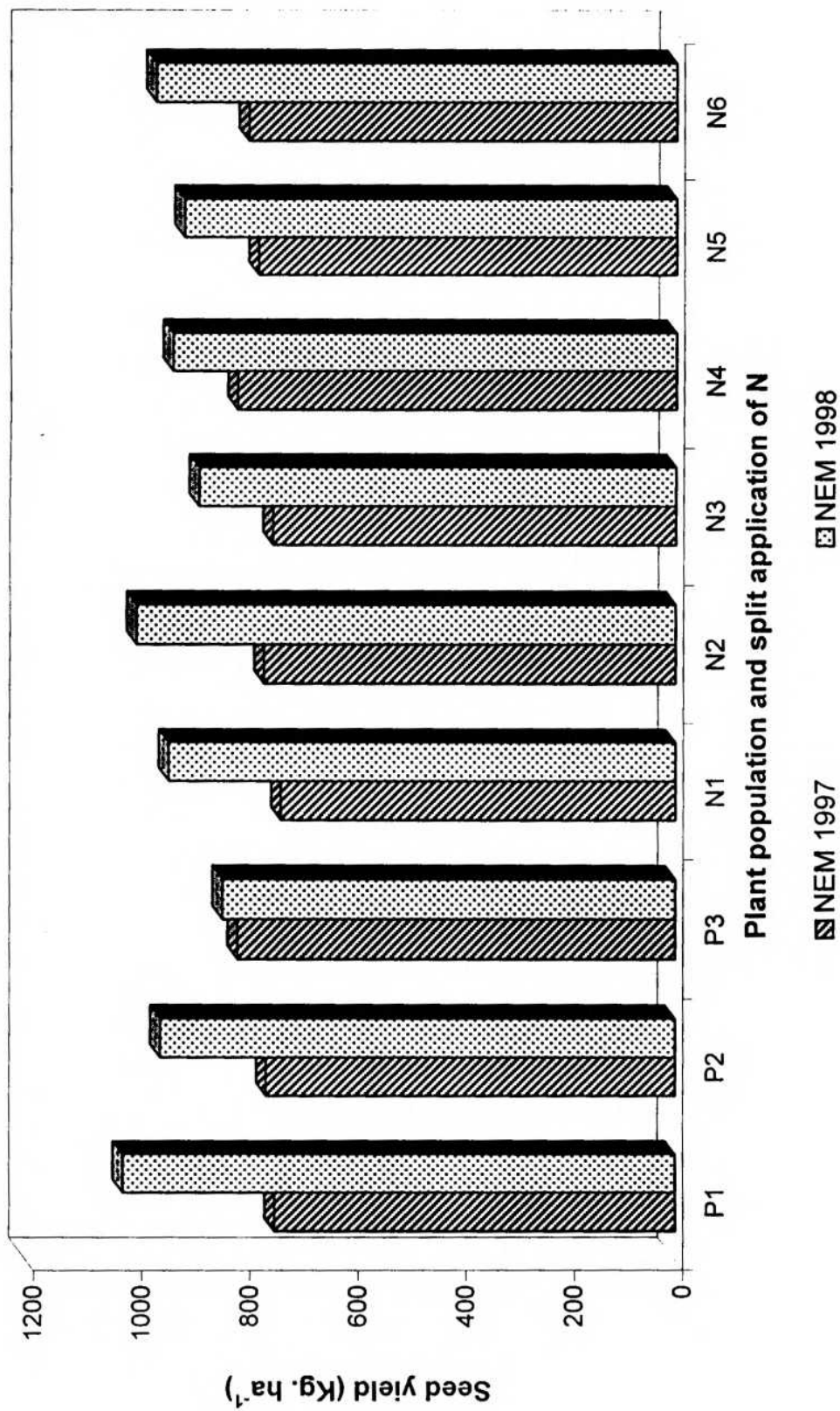
5.2.3. Yield attributes

Yield components of sunflower were favourably influenced by application of nitrogen in three splits (basal, 4th week after sowing and 6th week after sowing with rain) in different combinations. It was expected that when the nitrogen was applied in splits based on adequate soil moisture availability, the nutrient uptake could be increased substantially thereby resulting in higher yield attributing characters. Reduction in the values of yield components was observed in the treatment which received entire dose of nitrogen as basal. The lesser yield attributing characters under this treatment might be due to loss of nitrogen at the initial stages because of high intensity of rainfall, which affected the availability of nutrients at active vegetative and peak flowering stages. Application of N either in two or three splits recorded significantly higher head diameter, more filled seeds, higher seed filling percentage and 100 seed weight compared to full basal application of 40 kg N ha⁻¹. Increased yield attributes due to split application of N in sunflower was also reported by Manoharan *et al.* (1991).

5.2.4. Yield

Split application of N resulted in significant improvement in seed yield of sunflower. Application of nitrogen in three splits ($\frac{1}{2}$ basal + $\frac{1}{4}$ on 4th week after sowing + $\frac{1}{4}$ on 6th week after sowing with rain) increased the seed yield by 11.2 per cent over full basal application of N. Higher seed yield with split application of N was due to better growth and yield attributes of sunflower under favourable monsoon seasons as that of 1997, where dry spell is less common. Split application of nitrogen at varied growth stages of sunflower might have favoured greater accumulation of assimilates starting from initial stages, which might have

Fig. 9. Effect of plant population and split application of nitrogen on seed yield (Kg. ha⁻¹) of sunflower



translocated to yield components at the later part of the growth phase (Satao *et al.*, 1984). Better translocation of photosynthates to the reproductive parts was responsible for improvement in yield attributes of sunflower due to split application of N (Reddy and Gajendra Giri 1997; Manoharan *et al.*, 1991). Nitrogen use efficiency is more pronounced under adequate supply of soil moisture coupled with split application of nitrogen, which makes the plant to face no N stress throughout the crop growth period (Narayana and Patel, 1998). However in 1998, application of nitrogen in two equal split ($\frac{1}{2}$ basal + $\frac{1}{2}$ on 4th week after sowing with rain) recorded 9.53 per cent greater seed yield over three equal splits of N.

When compared to 1997, application of N in three splits in 1998 was not able to produce as much yield as that of two equal splits before 4th week or full basal application. This may be due to intermittent dry spell after 4th week, which created soil moisture deficit and the nutrient effect was less pronounced under inadequate supply of soil moisture. In 1998, when the split application of nitrogen was delayed beyond 4th week after sowing, the effect on seed yield was less pronounced because of lack of adequate nutrient uptake by sunflower after flowering stage (Reddy and Gajendra Giri, 1996).

Similarly in 1997, application of nitrogen in three splits ($\frac{1}{4}$ basal + $\frac{1}{2}$ on 4th week after sowing + $\frac{1}{4}$ on 6th week after sowing) produced 25.5 per cent greater stalk yield than full basal application. Split application of nitrogen upto flowering could accumulate more food material because of effective nitrogen utilization under adequate moisture conditions (Jayaraman, 1988). When the rainfall is more frequent, split applications of nitrogen could avoid various types of N losses. In 1998, nitrogen application in two equal splits ($\frac{1}{2}$ basal + $\frac{1}{2}$ on 4th week after sowing with rain) had

22.6 per cent higher stalk yield than nitrogen applied in two equal splits ($\frac{1}{2}$ N basal + $\frac{1}{2}$ on 6th week after sowing). This indicated that in 1998 the crop might have suffered due to water stress induced nitrogen stress at late vegetative and early flowering stages. Though during 1998, the terminal phase of sunflower crop has received above normal rainfall which soaked the soil thoroughly, the loss occurred due to water and nutrient stress at critical stages could not be compensated.

5.2.5. Quality parameters

In general, split application of N favourably influenced the protein content of sunflower seed in both the years when compared to full basal application of N. However, there was no marked difference between the N split application with respect to oil content. The possible reason for increased protein content with three split application of N may be the degradation of carbohydrates in TCA (Tri carboxylic acid) cycle which further degraded to acetyl CO-A (co enzyme A) and thus there would be more protein in plant cells with increased supply of nitrogen. Simultaneously, as the percentage of oil decreases, a very low amount of acetyl CO A is available for synthesis of fatty acid under adequate available nitrogen (Bahl *et al.*, 1997). Thus, it could be concluded from the result that when the nitrogen is limiting factor, oil content could be higher. Similar inverse relationship between oil and protein content was reported by Loof (1960).

5.2.6. Nutrient uptake

In general, nitrogen, phosphorus and potassium uptake of sunflower were higher from 30 DAS to harvest stage. However the nutrient uptake of sunflower was not influenced by N split application in a well distributed high rainfall year of 1997 at 30 DAS. This might be due to the high intensity rainfall at the initial stages which

Fig. 10. Effect of plant population and N split application on nitrogen uptake
(Kg. ha⁻¹) of sunflower - NEM, 1997

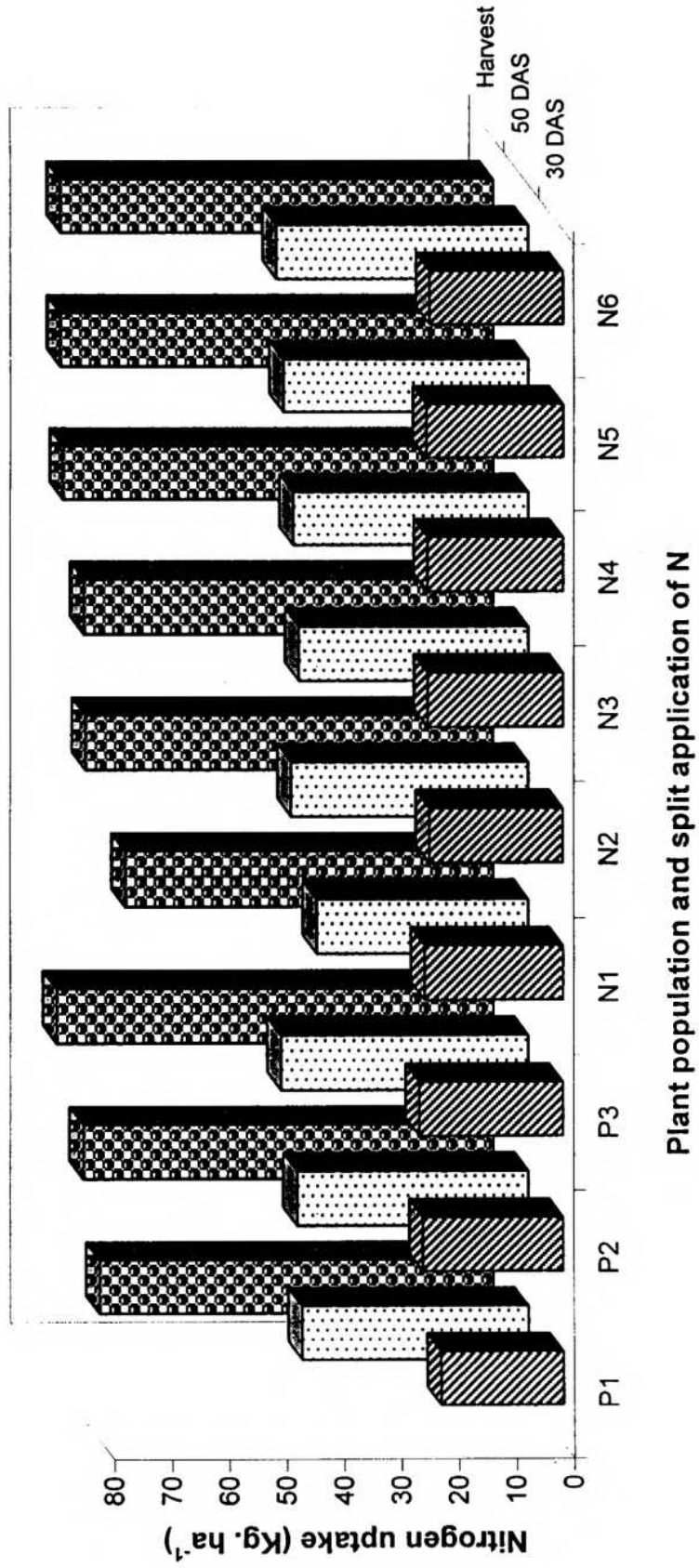
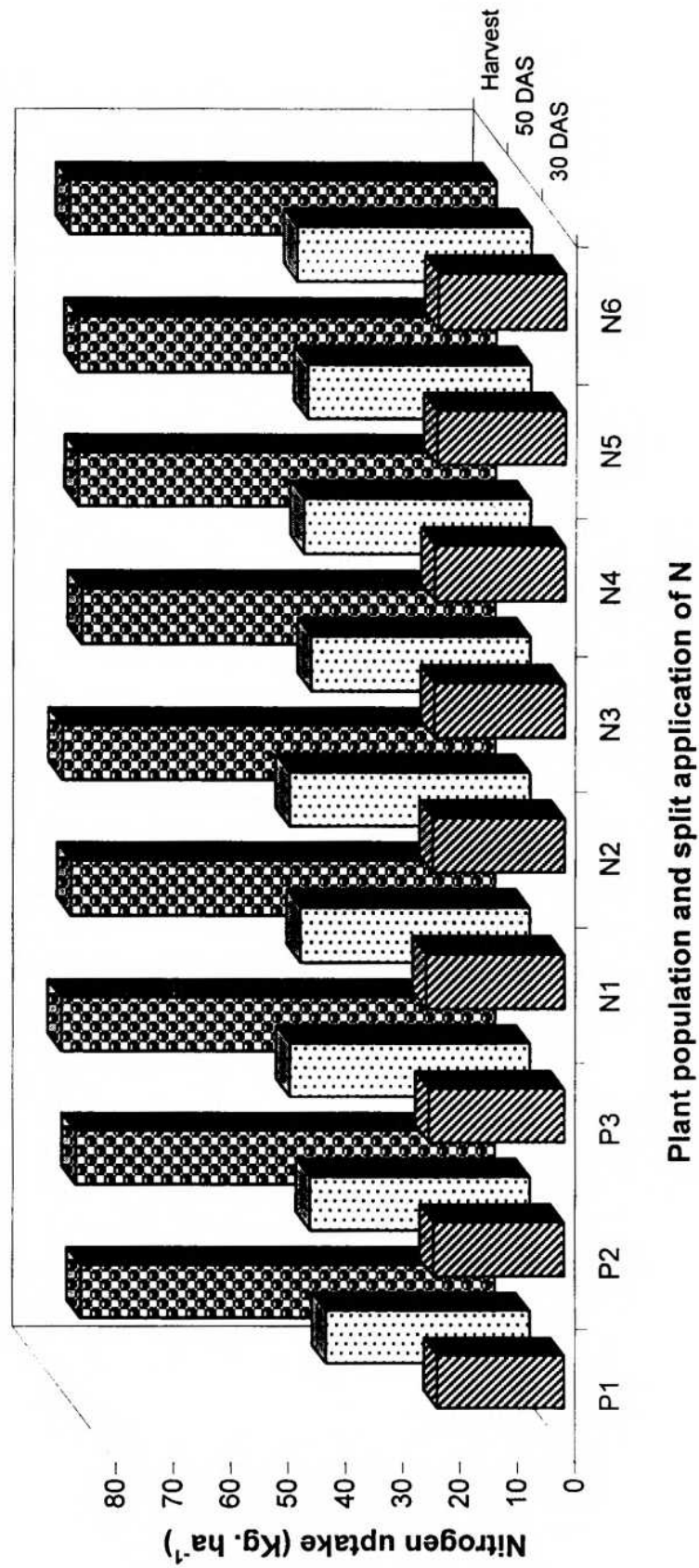


Fig. 11. Effect of plant population and N split application on nitrogen uptake
(Kg. ha⁻¹) of sunflower - NEM, 1998



nullified the effect of nitrogen split application treatments because of possible loss of N by leaching (Reddy and Gajendra Giri, 1996). However, during later stages, split application of N exerted significant difference in nutrient uptake and application of nitrogen in three splits lead to more uptake of N, P and K. Split application of nitrogen might have supplied N rationally at right stages for efficient utilization by sunflower plants with better growth which in turn increased the nutrient uptake. In 1998, full basal application of 40 N ^{kg ha⁻¹} at sowing registered higher N, P and K uptake at 30 DAS. However, in the later stages (50 DAS and at harvest), application of nitrogen in two equal splits tend to extract more N, P and K due to staggered N supply power of the soil.

5.2.7. Soil available nutrients

The soil available N at harvest during 1997 differed with respect to N split application treatments. However, the available P and K in 1997 and the available N, P and K in 1998, were not affected. The results clearly indicated that whenever part of the nitrogen requirement (50 per cent) by sunflower is applied 6 weeks after sowing, the crop could not take up the entire available nutrient, leaving major part in the soil itself. This might be the reason for greater soil available nitrogen when nitrogen was applied in two equal splits, half at basal and ½ at six weeks after sowing. However, mostly the effect was not significant due to the nature of the crop to utilise the entire quantity of available nutrients.

5.3. Interaction effect of plant population and nitrogen split application

The interaction effect of plant population and nitrogen split application was significant with respect to dry matter production at harvest stage of 1997 and seed yield of 1998. In 1997, though the interaction effect was observed for dry matter

Fig. 12. Economics and monetary returns of treatments in sunflower - NEM, 1997

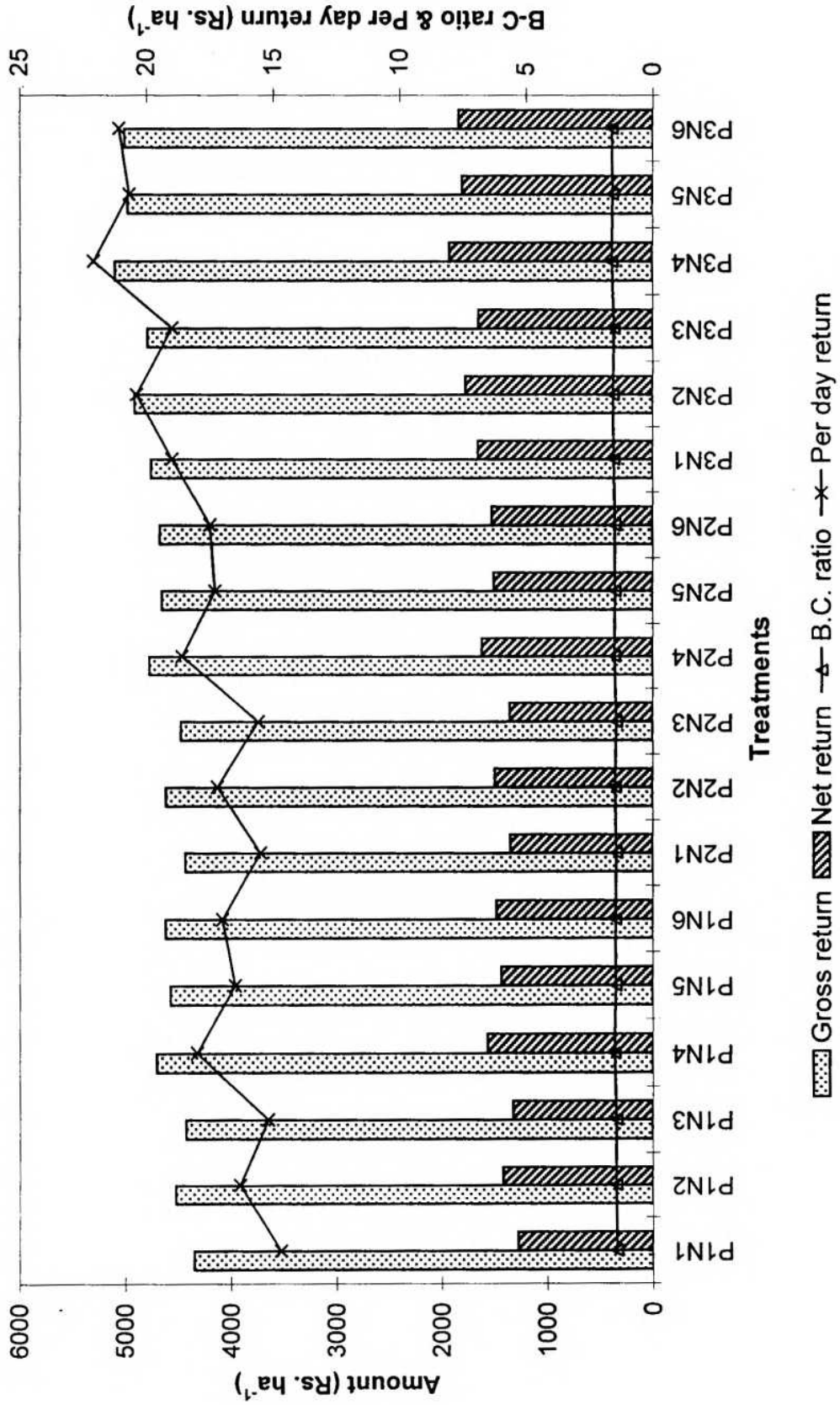
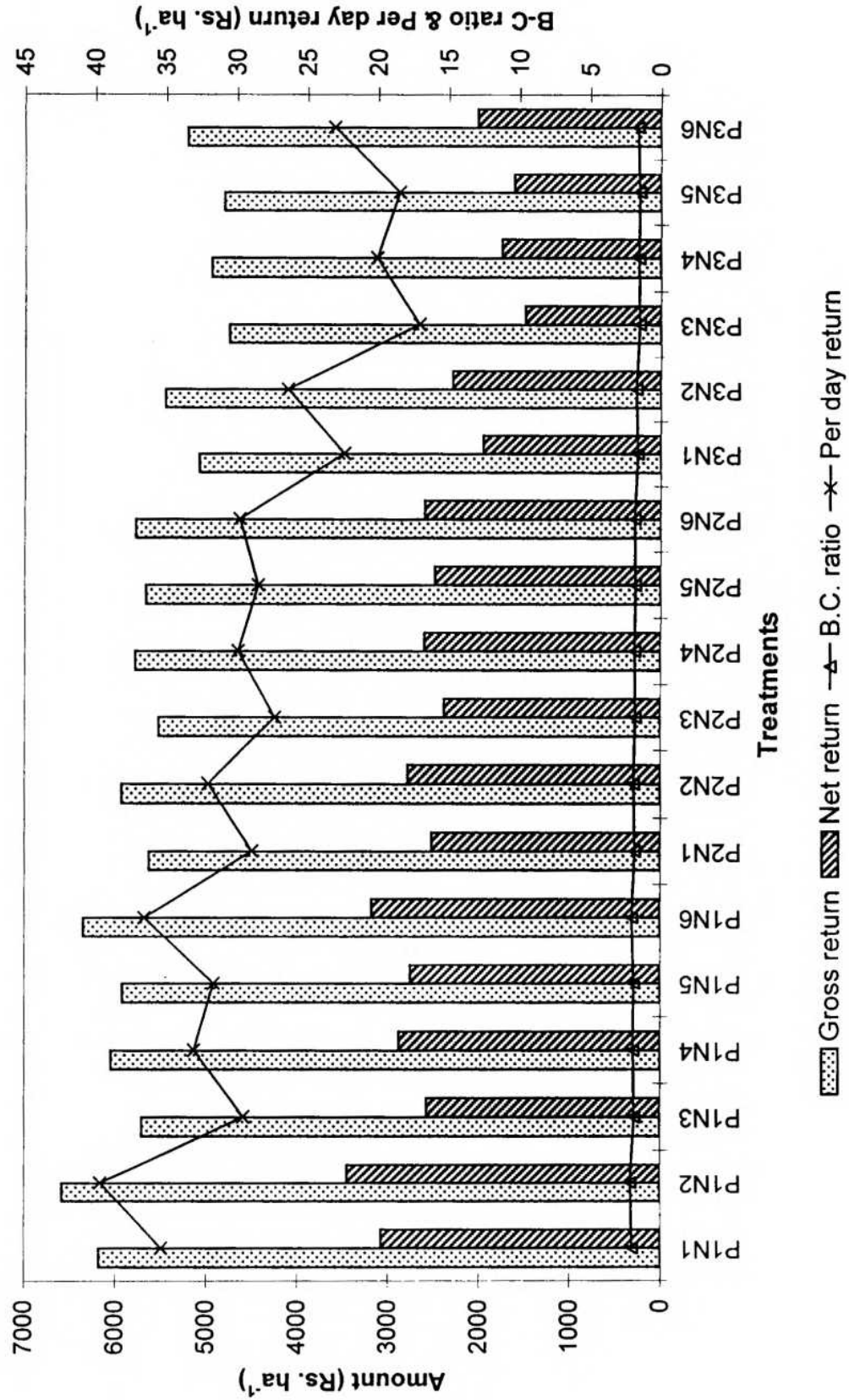


Fig. 13. Economics and monetary returns of treatments in sunflower - NEM, 1998



production at harvest stage, the same effect was not shifted towards seed yield. The results indicated that during 1997, seed yield at a given population level under different N split application practices were not significant because of uniform distribution of rainfall throughout the crop growth period (598 mm in 43 rainy days) which in turn did not limit the moisture availability across the treatments. However, in 1998, a given population level behaved differently under varied N split application treatments. The population level of 88,888 plants ha⁻¹ recorded significantly higher yield at nitrogen application in two equal splits (½ basal + ½ 4th week after sowing) before 30 DAS. However, the same population level at nitrogen application in three splits up to 45 DAS, failed to increase the seed yield probably because of intermittent dry spells. The rainfall data also indicated that, though the total quantity of rainfall received was above normal (571.2 mm), the distribution was erratic (20 rainy days) concentrated mostly during the initial stages. Kharwara and Bindra (1992) and Tenbe *et al.* (1996) also indicated the importance of soil moisture availability in deciding the interaction effect between plant population and N split application on yield of sunflower.

In 1997, highest benefit : cost ratio was observed in the treatment combination of higher plant population with three nitrogen split application. But in 1998, lower population with two equal splits before 30 DAS (½ basal + ½ on 4th week after sowing) with receipt of rainfall recorded higher net return and benefit : cost ratio. The difference in net return and B:C ratio between the treatments was caused only by the variation in seed yield in both the years.

Summary and Conclusion

CHAPTER VI

SUMMARY AND CONCLUSION

Field experiments were conducted during North East Monsoon seasons of 1997 and 1998, at Tamil Nadu Agricultural University Farm, Coimbatore to study the influence of plant population and N split application on growth and yield of sunflower crop under rainfed conditions. The experiment was laid out in split plot design with three replications. The main plot consisted of three plant populations viz., 30 x 37.5 cm (88,888 plants ha⁻¹), 30 x 30 cm (1,11,111 plants ha⁻¹) and 30 x 25 cm (1,33,333 plants ha⁻¹). The sub plots comprised of six N split applications viz., N₁ (full basal), N₂ (½ basal + ½ on 4th week after sowing with rain), N₃ (½ basal + ½ on 6th week after sowing with rain), N₄ (½ basal + ¼ on 4th week after sowing + ¼ on 6th week after sowing with rain), N₅ (1/3 basal + 1/3 on 4th week after sowing + 1/3 on 6th week after sowing with rain) and N₆ (¼ basal + ½ on 4th week after sowing + ¼ on 6th week after sowing with rain).

Growth components like plant height, stem girth, dry matter production and leaf area index were recorded. Yield attributes such as head diameter, filling percentage, number of filled seeds and 100 seed weight, seed and stalk yield were also taken. Growth analysis viz., LAI, CGR, RGR and NAR were estimated in both the years. The uptake of N, P and K at different stages were recorded.

Quality analysis was carried out wherein oil and crude protein content were estimated.

The conclusions arrived and the inference drawn from the observations of the study are summarised below.

In both the years, plant height was influenced by the closer spacing of 30 x 25 cm (1,33,333 plants ha⁻¹) at all the stages of observation. Similarly dry matter production was favourably influenced by closer spacing of 30 x 25 cm, while the stem girth was maximum under the wider spacing of 30 x 37.5 cm.

The growth analysis as computed by LAI and CGR were maximum with the spacing of 30 x 25 cm. During 1997, the RGR at 30-50 DAS was maximum under 30 x 30 cm (1,11,111 plants ha⁻¹) while at 50 DAS to harvest it was maximum at lower plant population (30 x 37.5 cm) of 88,888 plants ha⁻¹. In 1998, the population levels did not have any significant influence on RGR at both the stages (30-50 DAS and 50 DAS - harvest).

In 1997, the NAR was not significantly influenced by plant population at 30-50 DAS. But at 50 DAS to harvest, it was maximum under closer spacing of 30 x 25 cm (1,33,333 plants ha⁻¹). In 1998, the NAR at 30-50 DAS was higher at 1,33,333 plants ha⁻¹ while it was not significantly influenced by plant population at 50 DAS to harvest.

The number of days to fifty per cent flowering was not influenced by plant populations in both the years.

In both the years, lower plant population (30 x 37.5 cm) of 88,888 plants ha⁻¹ recorded maximum values of yield attributes like head diameter, total number of seeds head⁻¹, filling percentage and 100 seed weight. With regard to seed yield, in 1997, it was maximum under higher plant population (30 x 25 cm) of 1,33,333 plants ha⁻¹. But in 1998, the seed yield was maximum at lower plant population (30 x 37.5 cm) of 88,888 plants ha⁻¹. The straw yield was more at higher plant densities (30 x 25 cm) in both the years.

The oil content of sunflower was marginally high under higher plant population of 1,33,333 plants ha⁻¹ in both the years. The crude protein content was not significantly influenced by plant populations in 1997. While in 1998, the crude protein content was maximum with lower plant population (88,888 plants ha⁻¹).

During 1997, at 30 DAS, the effect of plant population on N, P and K uptake was not significant, whereas at 50 DAS and at harvest, higher plant population (1,33,333 plants ha⁻¹) recorded maximum N, P and K uptake. Similarly in 1998, at all the stages, maximum N, P and K uptake was noticed under higher plant population of 1,33,333 plants ha⁻¹.

The post harvest soil available N, P and K was not significantly influenced by plant population levels in both the years.

The net return, gross return, B.C. ratio and per day return were maximum at higher plant densities (30 x 25 cm) in 1997, whereas in 1998, they were higher at lower plant population (30 x 37.5 cm). Split application of N either at 2 or 3 splits recorded higher plant height, stem girth, LAI and DMP at all the growth stages during 1997.

In 1998, the growth attributes like plant height, stem girth, LAI and DMP were maximum under basal application of entire N (N₁), at 30 DAS. However, at 50 DAS and at harvest application of ½ N on 4th week after sowing recorded higher values on growth attributes. Split application of N recorded comparatively higher values on CGR, RGR and NAR at different growth stages in both the years when compared to basal application of entire N.

In both the years, split application of N did not show any significant influence on number of days to fifty per cent flowering.

The yield attributes like head diameter, total number of seeds, filling percentage and 100 seed weight were found to be influenced by N split application. In 1997, the values on these parameters were maximum under N_4 ($\frac{1}{2}$ basal + $\frac{1}{4}$ on 4th week after sowing + $\frac{1}{4}$ on 6th week after sowing with rain) whereas in 1998, N_2 ($\frac{1}{2}$ basal + $\frac{1}{2}$ on 4th week after sowing with rain) recorded higher values.

Sunflower seed yield and oil yield were maximum under N_4 ($\frac{1}{2}$ basal + $\frac{1}{4}$ on 4th week after sowing + $\frac{1}{4}$ on 6th week after sowing with rain) in 1997. While in 1998, the seed and oil yield were higher with application of 50 per cent N as basal + 50 per cent N as top dressing on 4th week after sowing with rain.

Stalk yield was maximum for N_6 ($\frac{1}{4}$ basal + $\frac{1}{2}$ on 4th week after sowing + $\frac{1}{4}$ on 6th week after sowing with rain) in 1997 while in 1998, N_2 ($\frac{1}{2}$ basal + $\frac{1}{2}$ on 4th week after sowing with rain) treatment was found to produce more stalk yield.

The oil content was maximum with full basal application of N_1 in 1997. Application of N in two splits N_3 ($\frac{1}{2}$ basal + $\frac{1}{2}$ on 6th week after sowing with rain) has recorded maximum oil content. The protein content of sunflower was maximum under N_4 ($\frac{1}{2}$ basal + $\frac{1}{4}$ on 4th week after sowing + $\frac{1}{4}$ on 6th week after sowing with rain) in 1997 the same was higher with N_2 ($\frac{1}{2}$ basal + $\frac{1}{2}$ on 4th week after sowing with rain) during 1998.

In 1997 at 30 DAS, N, P and K uptake was not significantly influenced by the split application of N. While at 50 DAS and at harvest stages it was maximum in N_6 ($\frac{1}{4}$ basal + $\frac{1}{2}$ on 4th week after sowing + $\frac{1}{4}$ on 6th week after sowing with rain).

But in 1998, N, P and K uptake at 30 DAS was maximum in N₁ (full basal). Whereas at 50 DAS and harvest stages N₂ (½ basal + ½ on 4th week after sowing with rain) treatment recorded maximum N, P and K uptake.

In 1997, the soil available N was maximum under N₃ (½ basal + ½ on 6th week after sowing with rain) and there was no significant difference among the treatments with regard to available P and K. Similarly in 1998, there was no significant difference between N applications and soil available N, P and K.

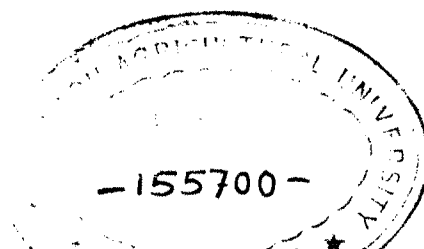
Net return, gross return, B.C. ratio and per day return were maximum under N₄ (½ basal + ¼ on 4th week after sowing + ¼ on 6th week after sowing with rain) in 1997, while the same were higher under N₂ (½ basal + ½ on 4th week after sowing with rain) in 1998.

From the study, it is concluded that higher plant population of 1,33,333 plants ha⁻¹ combined with N at 3 splits (½ N basal + ¼ on 4th week after sowing + ¼ on 6th week after sowing with rain) is best for getting higher yields in sunflower under rainfed conditions with high and uniform distribution of rainfall. But when there is moisture stress at vegetative and flowering stages due to uneven distribution of rainfall, lower plant population of 88,888 plants ha⁻¹ combined with recommended N in 2 splits (½ basal + ½ on 4th week after sowing with rain) is found to be most ideal for getting higher yields and economic returns.

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115

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* Original not seen.

Plates



General view of the experimental field



Recommended plant population (30 x 30 cm) with full basal application - NEM 1997



120% of recommended plant population
(30 x 25 cm) with nitrogen application as three splits
(N₄) - NEM 1997



80% of recommended plant population
(30 x 37.5 cm) with two N splits (N₂) Vs 120% of
recommended plant population (30 x 25 cm) with
three N splits (N₄) - NEM 1998

Appendices

APPENDIX - I
Weather data (NEM 1997)

Std week	Month and date	Rainfall (mm)	Temperature (°C)		Relative humidity (%)		Wind velocity (Km hr ⁻¹)	Solar radiation (Cal cm ⁻² day ⁻¹)	Evaporation (mm)
			Max.	Min.	07.22 hr	14.22 hr			
38	17-23 Sep.	2.8 (1)	32.6	22.1	80	49	14.0	364.5	5.8
39	24-30	-	32.8	22.1	79	39	21.0	438.2	7.6
40	01-07 Oct.	41.5 (2)	33.3	22.5	81	47	9.8	422.5	5.1
41	08-14	52.5 (2)	31.9	22.8	82	51	7.8	366.1	3.8
42	15-21	18.0 (3)	30.8	22.2	86	54	4.6	372.9	3.7
43	22-28	81.0 (6)	30.1	22.2	92	62	3.4	323.5	2.8
44	29-31 Oct. & 01-04 Nov.	136.0 (6)	29.6	22.1	89	68	3.2	334.0	1.6
45	05-11	50.2 (4)	28.4	22.0	92	69	3.3	341.5	2.4
46	12-18	45.5 (1)	30.3	21.8	89	60	2.9	401.7	3.1
47	19-25	101.0 (6)	29.3	22.2	91	67	2.9	378.4	1.7
48	26-30 Nov. & 01-02 Dec.	32.2 (4)	29.1	21.9	89	67	3.9	374.6	3.1
49	03-09 Dec.	21.3 (5)	27.3	21.4	91	70	3.9	285.4	2.6
50	10-16	5.8 (1)	29.9	21.0	67	38	3.8	390.9	2.9
51	17-23	10.2 (2)	28.8	22.7	90	66	5.8	297.0	2.8
52	24-31	-	29.2	20.9	87	49	6.0	422.8	3.8

* Figures in the paranthesis are number of rainy days.

APPENDIX - II
Weather data (NEM-1998)

Std week	Month and date	Rainfall (mm)	Temperature (°C)		Relative humidity (%)		Wind velocity (Km hr ⁻¹)	Solar radiation (Cal cm ⁻² day ⁻¹)	Evaporation (mm)
			Max.	Min.	07.22 hr	14.22 hr			
37	10-16 Sep.	2.0 (1)	30.8	23.4	74	52	17.4	389.0	6.8
38	17-23	-	32.2	22.1	79	48	13.4	416.8	6.6
39	24-30	73.9 (2)	29.4	22.3	90	71	4.3	281.9	2.4
40	01-07 Oct.	2.0 (1)	31.5	22.8	86	56	7.6	353.1	3.9
41	08-14	5.0 (1)	30.3	23.4	83	64	11.1	347.6	4.6
42	15-21	-	30.6	21.5	77	51	16.4	440.0	5.7
43	22-28	8.0 (1)	32.0	21.5	88	52	6.3	363.0	4.6
44	29-31 Oct. & 01-04 Nov.	103.3 (3)	29.9	21.8	91	68	5.9	295.7	3.7
45	05-11	213.4 (4)	28.4	22.4	91	64	4.4	347.7	1.5
46	12-18	2.0 (1)	31.0	19.7	88	53	2.7	434.5	4.0
47	19-25	-	31.2	20.8	87	55	4.2	418.8	3.4
48	26-30 Nov. & 01-02 Dec.	39.6 (1)	30.2	19.6	90	53	4.1	373.4	2.9
49	03-09	-	28.4	21.0	88	56	7.7	344.6	3.1
50	10-16	122.0 (5)	26.0	21.2	92	82	7.0	208.4	2.0
51	17-23	-	28.4	19.1	91	55	3.3	428.1	2.8

* Figures in the paranthesis are number of rainy days.

Appendix III Soil Available Moisture (mm) 1997

	15 DAFSR		30 DAFSR		45 DAFSR		60 DAFSR		75 DAFSR		At Harvest	
	15cm	30cm	15cm	30cm	15cm	30cm	15cm	30cm	15cm	30cm	15cm	30cm
P ₁	46.7	100.5	49.1	100.8	48.2	101.1	38.0	80.4	27.8	66.9	23.0	56.7
P ₂	44.2	102.5	48.1	103.2	46.7	99.3	36.8	78.4	28.9	67.8	20.2	51.3
P ₃	46.4	99.9	47.6	98.8	46.2	98.1	30.7	70.1	26.3	60.0	20.6	50.5
N ₁	41.6	102.5	55.1	103.5	43.4	95.3	36.7	80.1	26.1	56.0	27.6	58.7
N ₂	46.5	95.8	44.1	102.5	46.9	99.3	31.8	61.2	24.4	67.5	21.9	53.4
N ₃	47.2	105.4	48.9	102.6	50.8	103.9	37.9	80.4	29.6	60.9	18.0	42.8
N ₄	46.7	101.3	51.2	102.6	47.4	99.3	31.0	72.7	38.2	77.8	21.8	52.5
N ₅	48.5	104.1	48.9	95.4	47.6	100.5	47.8	90.4	20.1	60.3	23.7	56.1
N ₆	40.5	96.7	48.9	103.8	46.5	99.3	37.8	80.1	29.4	69.9	21.6	56.4

Initial soil available moisture at 15cm - 12.9 mm
 Initial soil available moisture at 30cm - 30.6 mm
 DAFSR - Days after first sowing rain

Appendix - IV Soil Available Moisture (mm) 1998

	15DAFSR		30 DAFSR		45 DAFSR		60 DAFSR		75 DAFSR		At Harvest	
	15cm	30cm	15cm	30cm	15cm	30cm	15cm	30cm	15cm	30cm	15cm	30cm
P ₁	26.3	56.7	25.3	48.6	47.9	96.9	26.9	58.2	22.9	50.1	29.7	65.1
P ₂	24.7	53.2	21.5	44.7	46.2	95.4	28.4	55.6	21.2	47.1	27.5	62.0
P ₃	24.4	50.0	19.2	42.1	40.3	90.9	24.3	50.7	19.7	44.1	26.4	58.3
N ₁	28.1	51.5	19.8	41.8	44.7	96.3	28.2	57.9	22.7	50.7	25.8	60.9
N ₂	21.8	51.7	22.2	47.4	45.3	95.4	21.7	54.6	21.4	48.7	29.1	59.8
N ₃	26.7	55.8	22.4	42.7	41.2	96.0	25.3	57.3	20.3	45.8	31.5	66.0
N ₄	30.2	64.0	30.7	56.8	42.1	90.3	27.2	52.0	20.7	45.3	28.5	60.3
N ₅	20.0	56.1	25.1	47.7	47.7	93.0	20.2	57.3	23.1	42.9	30.2	58.1
N ₆	26.1	54.3	21.3	45.3	47.6	92.7	26.4	50.1	20.9	52.4	29.8	61.2

Initial soil available moisture at 15cm - 14.3 mm

Initial soil available moisture at 30cm - 34.6 mm

DAFSR - Days after first sowing rain