PERFORMANCE OF PROSO MILLET (*Panicum miliaceum* L.) UNDER VARIED TIMES OF SOWIG AND LEVELS OF NITROGEN

By

KARNAM THULASIRAM DIMPLE

B.Sc. (Ag.)

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CHAIRPERSON: Dr. C. NAGAMANI

ANGRAU

DEPARTMENT OF AGRONOMY
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ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY
GUNTUR - 522 034, ANDHRA PRADESH

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DECLARATION

I, **Ms. KARNAM THULASIRAM DIMPLE,** hereby declare that the thesis entitled **"PERFORMANCE OF PROSO MILLET (*Panicum miliaceum* L.) UNDER VARIED TIMES OF SOWING AND LEVELS OF NITROGEN"** submitted to the **Acharya N.G. Ranga Agricultural University** for the degree of **Master of Science in Agriculture** is the result of original research work done by me. I also declare that no material contained in the thesis has been published earlier in any manner.

Place : TIRUPATI

Date :

(KARNAM THULASIRAM DIMPLE)
I.D. No. TAM/2018-07

CERTIFICATE

Ms. KARNAM THULASIRAM DIMPLE has satisfactorily prosecuted the course of research and that thesis entitled **"PERFORMANCE OF PROSO MILLET (*Panicum miliaceum* L.) UNDER VARIED TIMES OF SOWING AND LEVELS OF NITROGEN"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its part thereof has been previously submitted by her for a degree of any university.

Date :

(C. NAGAMANI)
Chairperson
Assistant Professor
Department of Agronomy
S. V. Agricultural College
Tirupati-517 502

CERTIFICATE

This is to certify that the thesis entitled **"PERFORMANCE OF PROSO MILLET (*Panicum miliaceum* L.) UNDER VARIED TIMES OF SOWING AND LEVELS OF NITROGEN"** submitted in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (Agriculture) in AGRONOMY** of the Acharya N.G. Ranga Agricultural University, Guntur is a record of the bonafide original research work carried out by **Ms. KARNAM THULASIRAM DIMPLE** under our guidance and supervision.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all assistance received during the course of the investigations have been duly acknowledged by the author of the thesis.

Thesis approved by the Student's Advisory Committee

Chairperson	:	**Dr. C. NAGAMANI** Assistant Professor Department of Agronomy S.V. Agricultural College Tirupati-517 502, A.P.	________________
Member	:	**Dr. V. CHANDRIKA** Professor Department of Agronomy S.V. Agricultural College Tirupati-517 502, A.P.	_________________
Member	:	**Dr. A. R. NIRMAL KUMAR** Assistant Professor Department of Crop Physiology S.V. Agricultural College Tirupati-517 502, A.P.	_________________

Date of final viva-voce:

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LIST OF SYMBOLS AND ABBREVIATIONS

%	:	Per cent
@	:	At the rate of
°C	:	Degree centigrade
AOAC	:	Association of Official Analytical Chemists
B:C ratio	:	Benefit-Cost ratio
CD (P=0.05)	:	Critical difference at 5 per cent level of significance
cm	:	Centimeter
cm^2	:	Square centimeter
DAS	:	Days after sowing
dS m^{-1}	:	DeciSiemen per meter
EC	:	Electrical conductivity
et al.	:	And other people
Fig.	:	Figure
FN	:	Fortnight
g	:	Gram
ha^{-1}	:	Per hectare
i.e.	:	That is
K	:	Potassium
K_2O	:	Potassium Oxide
Kg	:	Kilogram
LAI	:	Leaf Area Index
m	:	Meter
m^{-2}	:	Per square metre
mm day^{-1}	:	Millimetre per day

$ml\ l^{-1}$	:	Millilitre per litre
NS	:	Non Significant
pH	:	Potential of Hydrogen ion concentration
P_2O_5	:	Phosphorus pentoxide
$Plant^{-1}$	:	Per plant
$q\ ha^{-1}$	:	Quintal per hectare
₹ ha^{-1}	:	Rupees per hectare
SEm±	:	Standard error of mean
SSP	:	Single Super Phosphate
$t\ ha^{-1}$	:	tonnes per hectare
viz.,	:	Namely

ABSTRACT

Name of the Authour	:	**KARNAM THULASIRAM DIMPLE**
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A field experiment entitled **"Performance of proso millet (*Panicum miliaceum* L.) under varied times of sowing and levels of nitrogen"** was carried out during *kharif*, 2019 on sandy loam soils of dryland farm of S.V. Agricultural College, Tirupati campus of Acharya N.G. Ranga Agricultural University. The present experiment was laid out in a split-plot design and replicated thrice. The treatments include four times of sowing *viz.*, II FN of June (S_1), I FN of July (S_2), II FN of July (S_3) and I FN of August (S_4) as main plots and four levels of nitrogen *viz.*, control (N_1), 20 kg N ha^{-1} (N_2), 40 kg N ha^{-1} (N_3) and 60 kg N ha^{-1} (N_4) as sub plots. The soil of the experimental field was sandy loam, neutral in soil reaction, low in organic carbon and available nitrogen, medium in available phosphorus and available potassium. The test variety of proso millet was DHPM-2769.

There was a significant improvement in growth parameters of proso millet (plant height, leaf area index, dry matter production and number of tillers m^{-2}) due to II FN of June (S_1) sowing relative to that of I FN of July (S_2) and II FN of July (S_3). The lowest stature of growth parameters were recorded with I FN of August (S_4) sown crop. Application of 60 kg N ha^{-1} (N_4) significantly improved the growth parameters at all the stages of sampling, while their lowest were with control (N_1). Interaction of the treatments could not vary the growth parameters significantly.

Longer duration to 50 per cent flowering and maturity was with the crop sown during II FN of June (S_1) which was significantly longer than that with later sowings. With regard to nitrogen levels, higher dose of nitrogen @ 60 kg N ha^{-1} (N_4) resulted in significantly earlier flowering and maturity than with 40 kg N ha^{-1} (N_2) and the latter was however on par with

that of 20 kg N ha^{-1} (N_2). Delay in 50 per cent flowering and maturity was noticed with no nitrogen application (N_1).

Yield attributes (number of panicles m^{-2}, length of the panicle, weight of grains panicle^{-1} and 1000 grain weight), grain and straw yield of proso millet responded significantly to times of sowing and levels of nitrogen. Significantly higher stature of yield attributes and yield were recorded with the crop sown during II FN of June (S_1) than with I FN of July (S_2) except for the number of panicles m^{-2} and length of the panicle which were found to be on par with each other. The lowest yield attributes and yield were with the crop sown during I FN of August (S_4). Application of 60 kg N ha^{-1} (N_4) significantly improved yield attributes and yield compared with that of 40 kg N ha^{-1} (N_3) and 20 kg N ha^{-1} (N_2), while their lowest were with control (N_1). Interaction of time of sowing and nitrogen levels could not vary the yield attributes and yield significantly.

Sowing of proso millet during I FN of August (S_4) resulted in higher post harvest soil available nutrients (N, P_2O_5 and K_2O) followed by that with II FN of July (S_3) and I FN of July (S_2) in the order of descent with significant disparity between any two of them. Crop sown during II FN of June (S_1) resulted in significantly lower post harvest soil available nutrients. Significantly higher post harvest soil available nitrogen was with 60 kg N ha^{-1} (N_4) compared to that of 40 kg N ha^{-1} (N_3), while the lowest was with control (N_1). The highest soil available phosphorus and potassium were with control (N_1) whereas application of 60 kg N ha^{-1} (N_4) resulted in significantly lower soil available phosphorus and potassium.

The nutrient (N, P and K) uptake at harvest of proso millet was significantly higher with early sown crop *i.e.* during II FN of June (S_1) than that with I FN of July (S_2). Significant reduction in nutrient uptake was observed with delay in sowing from II FN of July (S_3) to I FN of August (S_4). Application of 60 kg N ha^{-1} (N_4) resulted in higher nutrient uptake, which was significantly higher than with 40 kg ha^{-1} (N_3). The lowest nutrient uptake was with control (N_1).

The maximum gross returns, net returns and benefit:cost ratio were obtained with II FN of June (S_1) sown crop. Delay in sowing from I FN of July (S_2) to I FN of August (S_4) significantly reduced the economic returns. Application of 60 kg N ha^{-1} (N_4) resulted in significantly higher gross returns, net returns and benefit:cost ratio compared to the lower levels of nitrogen.

From the present study, it can be concluded that proso millet sown during II FN of June (S_1) along with 60 kg N ha^{-1} (N_4) proved to be promising in realizing higher grain yield and economic returns.

Chapter –I

Introduction

Chapter I

INTRODUCTION

Millets are ancient super grains, the reservoirs of nutrition for a better health. These are the annual grasses which are small seeded and native to many parts of the world. Millets can be cultivated in a wide range of soils and climatic conditions and are of special importance in semiarid regions because of their short growing seasons (Schery, 1963). The resilience exhibited by millets is helpful in adjusting themselves to various kinds of ecological niches. Even until 50 years ago millets were the major grain crops grown in India. From a staple food and integral part of local food cultures, just like many other things, millets have come to be looked down upon by modern urban consumers as "coarse grains"- Something that their village ancestors may have lived on, but that they had left behind and exchanged for a more "refined" diet. Unfortunately, this said refined diet lacks the nutrients critically important for us.

Statistics regarding the area and production with special reference to the proso millet has not been reported so far. However combined values for minor millets have appeared in which proso millet is considered. In India, minor millets (*kharif*) are grown in an area of 6.19 lakh hectares, with an annual production of 4.42 lakh tonnes and productivity of 714 kg ha^{-1} (*www.indiastat.com*, 2018). In Andhra Pradesh, the minor millets are being cultivated in an area of 31,000 hectares with 24,000 tonnes of production and 774 kg ha^{-1} productivity (*www.indiastat.com*, 2018).

Proso millet has also been called common millet, hog millet, broom corn, yellow hog, Hershey and white millet (Baltensperger, 1996). It is a warm-season crop capable of producing seed within 60 to 100 days after planting. Because of it's relatively short growing season, it has low moisture requirement and is capable of producing food or feed where other grain crops would fail. It is often planted as an emergency cash crop for situations where other crops have failed, been hailed out or where never planted due to unfavourable conditions. The crop is able to evade drought by it's quick maturity. As a crop in rotation, it has the advantage of enhancing weed control, especially with winter annual grasses in winter wheat (Nelson and Daigger, 1975). All these have made the crop quite indispensible to rainfed, tribal and hilly agriculture where crop substitution is difficult.

The protein content in the proso millet caryopsis is comparable to maize and wheat and it varies between 11.5 to 13 per cent and have long storability under ambient conditions and hence, suitable as famine reserve (Ramesh *et al.,* 1998). Native starch of proso millet shows maximum digestibility of 50 per cent (compared to other millets), dietary fibre of 9.6 per cent and lipid content of 3.5 to 6.7 per cent. The husked grain (about 70 % of the whole grain) is nutritious and is eaten whole, boiled and cooked like rice. Sometimes, it is ground to make roti and eaten. Starch is the main carbohydrate in the grain and is similar to corn starch, suitable as a sizing agent in the textile industry. Seed also have medicinal properties and can be used as demulcent and to treat abscesses and boils. Stem and root decoctions are suggested to be taken against hematuria.

A major problem in semi-arid regions during *kharif* with short rainy season is to determine the optimum time of sowing. Optimum time of sowing enables the crop to experience the favourable environmental conditions during various phenological stages, resulting in better performance of the crop. Mineral nutrition is an important factor responsible for exploiting yield potential in millets. Among the major nutrients, nitrogen plays an important role in increasing the productivity of a crop as it is known that response of grass family plants to nitrogen application is universal. Adequate nitrogen nutrition is required for initial establishment, vigorous growth, full development of tillers and leaves that enables the plant to operate at peak photosynthetic capacity, higher protein content of grain and hence results in production of quality grains. Therefore, the choice of sowing time and fertilizer application are considered to be the most important agronomic management options to optimize the yield of a crop.

Keeping all these in view, the field experiment entitled “Performance of proso millet (*Panicum miliaceum* L.) under varied times of sowing and levels of nitrogen” was undertaken with the following objectives:

1. To identify the suitable time of sowing of Proso millet in Southern Agro-Climatic Zone of Andhra Pradesh
2. To find out the optimum dose of nitrogen for higher growth and yield of Proso millet
3. To study the interaction between time of sowing and graded levels of nitrogen

Chapter – II

Review of Literature

Chapter II

REVIEW OF LITERATURE

The literature available pertinent to the present study "Performance of proso millet under varied times of sowing and levels of nitrogen" in India and abroad is presented in this chapter. Though the present study was carried out during *kharif* on proso millet, the work done during *kharif, rabi* and summer on proso millet and other millets has been reviewed.

2.1 GROWTH AND YIELD OF PROSO MILLET AS INFLUENCED BY TIMES OF SOWING

2.1.1 Growth Parameters

2.1.1.1 Plant height

Pandiselvi *et al.* (2010) recorded significantly taller plants of finger millet when sown on 24th May compared to that of 17th May sown crop on sandy loam soils of Karaikal, Puducherry.

Deshmukh *et al.* (2013) observed significantly higher plant height of pearlmillet when the crop was sown on 25th January than on 5th February and 15th February on black cotton soils of Navsari, Gujarat.

Siddig *et al*. (2013) noticed comparable plant height of pearlmillet with early (15th July) and late (August 1st) sowings on sandy loam and clay loam soils of Zalinger, Sudan.

Gavit *et al.* (2017) reported that proso millet produced significantly taller plants when sown on 24th June compared to the crop sown on 10th June on sandy clay loam soils of Dapoli, Maharashtra.

Foxtail millet sown on 30th June produced significantly taller plants than sown on 30th July on red sandy clay loam soils at Shivamogga, Karnataka (Nandini and Sridhara, 2019).

2.1.1.2 Leaf area index

Significantly higher leaf area index of finger millet was recorded when crop was sown during I FN of June compared to that of I FN of July on sandy loam soils of Dharward, Karnataka (Ashoka and Halikatti, 1997).

Pandiselvi *et al.* (2010) recorded higher leaf area when finger millet was sown on 17th May, but was however found to be on par with that of 24th May and 31st May sown crop on sandy loam soils of Karaikal, Puducherry.

Significantly higher leaf area of pearlmillet was noticed with early sown crop (15th July) compared to that of late sown crop (1st August) on sandy loam and clay loam soils of Zalinger, Sudan (Siddig *et al.*, 2013).

Nandini and Sridhara (2019) recorded significantly higher leaf area of foxtail millet when sown on 30th June than that sown on 30th July on red sandy clay loam soils of Shivamogga, Karnataka.

2.1.1.3 Dry matter production

Ashoka and Halikatti (1997) recorded significantly higher dry matter accumulation when finger millet was sown during I FN of June compared to the crop sown during II FN of June on sandy loam soils of Dharward, Karnataka.

Pandiselvi *et al.* (2010) reported that finger millet sown on May 17th produced significantly higher dry matter compared to that of sowing done on 7th June but was found to be on par with that of 24th May on sandy loam soils of Karaikal, Puducherry.

Deshmukh *et al.* (2013) reported that on black cotton soils of Navsari, Gujarat, pearlmillet produced significantly higher dry matter when sowing was done on 25th January compared with that of 5th February.

Significantly higher dry matter production of proso millet was recorded with the crop sown on 24th June compared to that with 10th June and 8th July on sandy clay loam soils of Dapoli, Maharashtra (Gavit *et al*., 2017).

2.1.1.4 Number of tillers m^{-2}

Gavit *et al.* (2017) noticed maximum number of tillers m^{-2} when proso millet was sown on 24th June compared with that of 10th June and 8th July sown crop on sandy clay loam soils of Dapoli, Maharashtra.

2.1.1.5 Days to 50 per cent flowering

Minimum number of days to 50 per cent flowering was observed when finger millet was sown during II FN of July compared to the crop sown during I FN of June and II FN of June on sandy loam soils of Dharward, Karnataka (Ashoka and Halikatti, 1997).

Deshmukh *et al.* (2013) reported that pearlmillet has taken significantly more time for 50 per cent flowering when sowing was done on 25th January than on 15th February, but the former was however comparable with the crop sown on 5th February on black cotton soils of Navsari, Gujarat.

Siddig *et al.* (2013) reported that in pearlmillet days to 50 per cent flowering was comparable when crop was sown early (15th July) and late (1st August) on sandy loam and clay loam soils of Zalinger, Sudan.

2.1.1.6 Days to maturity

Ashoka and Halikatti (1997) reported that finger millet required minimum number of days to reach physiological maturity when sown during II FN of July compared to the crop sown during I FN and II FN of June on sandy loam soils of Dharward, Karnataka.

It was observed that pearlmillet has taken more number of days to reach maturity when sown late (1st August) compared to the crop sown early (15th July) on sandy loam and clay loam soils of Zalinger, Sudan (Siddig *et al*., 2013).

2.1.2 Yield Attributes

2.1.2.1 Number of panicles m^{-2}

Gavit *et al.* (2017) reported that on sandy clay loam soils of Dapoli, Maharashtra, proso millet produced significantly higher number of panicles m^{-2} when the crop was sown on 24th June compared to the crop sown on 10th June and 8th July.

2.1.2.2 Length of the panicle

Significantly higher finger length in finger millet was observed on sandy loam soils of Dharward, Karnataka when crop was sown during I FN of June compared to that of I FN and II FN of July, but was however found to be on par with the crop sown during II FN of June (Ashoka and Halikatti, 1997).

Pandiselvi *et al.* (2010) recorded maximum length of finger when finger millet was sown on 17th May than on 21st June on sandy loam soils of Karaikal, Puducherry.

On black cotton soils of Navsari, Gujarat significantly increased earhead length of pearlmillet was noticed when crop was sown on 5th February than on 15th February, but the former was however comparable with the crop sown on 25th January (Deshmukh *et al.*, 2013).

Siddig *et al.* (2013) observed higher panicle length of pearlmillet when sowing was done on 15th July, but was however comparable with that of 1st August sown crop on sandy loam and clay loam soils of Zalinger, Sudan.

Proso millet resulted in significantly lengthier panicles when sowing was done on 24th June than on 10th June and 8th July on sandy clay loam soils of Dapoli, Maharashtra (Gavit *et al.*, 2017).

Nandini and Sridhara (2019) noticed significantly higher panicle length in foxtail millet when crop was sown on 30th June than that of 30th July and 30th August on red sandy clay loam soils at Shivamogga, Karnataka.

2.1.2.3 Weight of grains panicle^{-1}

Ashoka and Halikatti (1997) recorded significantly higher ear head weight in finger millet when the crop was sown during I FN of June compared to that of I FN and II FN of July on sandy loam soils of Dharward, Karnataka.

Gavit *et al.*(2017) reported that on sandy clay loam soils of Dapoli, Maharashtra, proso millet sown on 24th June resulted in higher weight of panicle than that of 10th June and 8th July.

Foxtail millet sown during II FN of June resulted in significantly higher earhead weight than that of I FN of July on medium black soils of Raichur, Karnataka (Mubeena *et al*., 2019).

Significant increase in panicle weight was noticed in foxtail millet when sowing was done on 30th June than on 30th July and 30th August on red sandy clay loam soils at Shivamogga, Karnataka (Nandini and Sridhara, 2019).

2.1.2.4 1000 grain weight

Test weight of finger millet was not affected by the times of sowing during *kharif* on sandy loam soils of Dharward, Karnataka (Ashoka and Halikatti, 1997).

On sandy loam soils of Karaikal, Puducherry significantly more test weight of finger millet was recorded when crop was sown on 31st May compared to that of May 17th and May 24th (Pandiselvi *et al.*, 2010).

Significantly higher 1000 grain weight of pearlmillet was recorded when the crop was sown on 25th January than that with 15th February on black cotton soils of Navsari, Gujarat (Deshmukh *et al.*, 2013).

Siddig *et al*. (2013) noticed that 1000 grain weight of pearlmillet resulted from sowing done on 15th July and 1st August were comparable on sandy loam and clay loam soils of Zalinger, Sudan.

Gavit *et al.* (2017) reported that proso millet sown on 24^{th} June recorded significantly higher 1000 grain weight than that with 10^{th} June and 8^{th} July on sandy clay loam soils of Dapoli, Maharashtra.

Mubeena *et al*. (2019) recorded significantly higher 1000 grain weight of foxtail millet when crop was sown during II FN of June compared to that of I FN of July on medium black soils of Raichur, Karnataka.

Significantly higher 1000 grain weight of foxtail millet was noticed with the crop sown on 30^{th} June than that of 30^{th} July on red sandy clay loam soils at Shivamogga, Karnataka (Nandini and Sridhara, 2019).

2.1.3 Yield

2.1.3.1 Grain yield

On sandy loam soils of Dharward, Karnataka grain yield of *kharif* finger millet increased significantly when the crop was sown during I FN of June compared to that of II FN of June and I FN of July sowings (Ashoka and Halikatti, 1997).

Finger millet sown during 23^{rd} Meteorological week (4^{th} – 10^{th} June) resulted in maximum grain yield compared to that of crop sown during 22^{nd} Meteorological week (28^{th} May – 3^{rd} June) on shallow laterite soils of Kolhapur, Maharashtra (Ramshe *et al*., 2003).

Pandiselvi *et al.* (2010) reported that finger millet sown on 17^{th} May produced significantly higher grain yield than that of 24^{th} May on sandy loam soils of Karaikal, Puducherry.

Deshmukh *et al.* (2013) reported that delay in sowing from 5^{th} February to 15^{th} February reduced the grain yield of pearlmillet significantly on black cotton soils of Navsari, Gujarat.

Siddig *et al*. (2013) realized significantly higher grain yield of pearlmillet when sowing was done on 15^{th} July than that of 1^{st} August on sandy loam and clay loam soils at Zalinger, Sudan.

Pearlmillet sown on 23rd July resulted in higher grain yield, which was however on par with that of 30th July and 6th August sown crop on sandy loam soils of Allahabad, Uttar Pradesh (Maurya *et al*., 2016).

Gavit *et al.* (2017) reported that proso millet sown on 24th June produced significantly higher grain yield than that of 10th June and 8th July on sandy clay loam soils of Dapoli, Maharashtra.

Comparable grain yields of foxtail millet was noticed with the crop sown during II FN of June and I FN of July on medium black soils of Raichur, Karnataka (Mubeena *et al*., 2019).

Significantly higher grain yield of foxtail millet was registered when sowing was done on 30th June than that of 30th July on red sandy clay loam soils of Shivamogga, Karnataka (Nandini and Sridhara, 2019).

2.1.3.2 Straw yield

Ashoka and Halikatti (1997) recorded significantly higher straw yield of finger millet on sandy loam soils of Dharward, Karnataka when the crop was sown during I FN of June compared to that of II FN of July, but was found to be on par with that of sowings done during II FN of June and I FN of July.

Drilling of finger millet during 22nd Meteorological week (4th – 10th June) resulted in the maximum straw yield on shallow laterite soils of Kolhapur, Maharashtra (Ramshe *et al*., 2003).

Deshmukh *et al.* (2013) reported that on black cotton soils of Navsari, Gujarat pearlmillet produced significantly higher straw yield when sown on 5th February than that of 15th February, but was however on par with the crop sown on 25th January.

Gavit *et al.* (2017) reported that proso millet sown on 24th June produced significantly higher straw yield than with the crop sown on 10th June and 27th July on sandy clay loam soils of Dapoli, Maharashtra.

Foxtail millet sown on 30th June resulted in significantly higher straw yield than that of 30th July and 30th August on red sandy clay loam soils of Shivamogga, Karnataka (Nandini and Sridhara, 2019).

2.1.4. Post Harvest Soil Nutrient Status

Gavit *et al.* (2017) reported that time of sowing of proso millet did not significantly influence the post harvest soil available nitrogen, phosphorus and potassium on sandy clay loam soils of Dapoli, Maharashtra.

2.1.5. Nutrient Uptake at Harvest

The highest nutrient uptake (N, P and K) at harvest by the crop was recorded when pearlmillet was sown on 5th February compared to that of 15th February on black cotton soils of Navsari, Gujarat (Deshmukh *et al.*, 2013).

Mubeena *et al.* (2019) reported that nutrient uptake (N, P and K) at harvest of foxtail millet was significantly higher with the crop sown during II FN of June compared to that of I FN of July on medium black soils of Raichur, Karnataka.

2.1.6 Economics

Ramshe *et al.* (2003) reported that finger millet gave higher gross returns, net returns and benefit:cost ratio when sowing was done during 23rd Meteorological week (MW) compared to that of 24th MW on shallow laterite soils of Kolhapur, Maharashtra.

Maximum net returns and benefit:cost ratio were realized when pearlmillet was sown on 5th February compared to that with 25th January and 15th February on black cotton soils of Navsari, Gujarat (Deshmukh *et al.*, 2013).

Significantly higher gross returns, net returns and benefit:cost ratio of foxtail millet was obtained with the crop sown during II FN of June compared to that of I FN of July on medium black soils of Raichur, Karnataka (Mubeena *et al*., 2019).

2.2 GROWTH AND YIELD OF PROSO MILLET AS INFLUENCED BY LEVELS OF NITROGEN

2.2.1 Growth Parameters

2.2.1.1 Plant height

Plant height of proso millet increased significantly with application of 150 kg N ha^{-1} compared with that of 75 and 225 kg N ha^{-1} on clay loam soils of Bursa, Turkey (Turgut *et al*., 2006).

Significant increase in plant height of kodo millet was noticed on sandy loam soils with increase in nitrogen level from 0 to 40 kg ha^{-1} at Rewa, Madhya Pradesh (Singh and Maurya, 2013).

Hasan *et al*. (2013) reported that in foxtail millet application of $N_{30}\,P_{24}\,K_{15}$ kg ha^{-1} produced significantly taller plants compared with that of no fertilizer ($N_0\,P_0\,K_0$ kg ha^{-1}) application on sandy loam soils of Joydebpur, Bangladesh.

Significantly taller plants of barnyard millet were noticed with application of 100 per cent recommended dose of nutrients (40:20:20 NPK kg ha^{-1}) compared to lower levels on silty clay loam soils of Ranichauri, Uttarakhand (Yadav and Yadav, 2013).

Munirathnam and Kumar (2015) observed significantly taller plants of white ragi varieties with application of 80 kg N ha^{-1} than that with 40 kg N ha^{-1}, but was statistically similar with application of 60 kg N ha^{-1} on vertisols of Nandyal, Andhra Pradesh.

Significantly higher plant height of finger millet was noticed with application of 125 per cent of recommended dose of nitrogen (75 kg N ha^{-1}) compared to that of 100 per cent RDN (60 kg N ha^{-1}) on sandy loam soils at Jagdalpur, Chhattisgarh (Pradhan *et al*., 2015).

Foxtail millet produced significantly taller plants on sandy loam soils with application of 50 kg N ha^{-1} over 25 kg N ha^{-1} at Tirupati, Andhra Pradesh (Jyothi *et al*., 2016).

Application of 75 kg N ha^{-1} to pearlmillet resulted in significantly taller plants than that with 45 kg N ha^{-1}, but was however on par with that of 60 kg N ha^{-1} on clayey loam soils of Parbhani, Maharashtra. (Arshewar *et al*., 2018).

Charate *et al.* (2018) recorded significantly higher plant height of little millet with application of 60 kg N ha^{-1} than with that of 20 kg N ha^{-1}, however it was on par with that of 40 kg N ha^{-1} on *alfisols* of Bengaluru, Karnataka.

2.2.1.2 Leaf area index

Significantly higher leaf area of finger millet was recorded with application of 125 per cent of recommended dose of nitrogen (75 kg N ha^{-1}) compared to that of 100 per cent RDN (60 kg N ha^{-1}) on sandy loam soils of Jagdalpur, Chhattisgarh (Pradhan *et al*., 2015).

Jyothi *et al*. (2016) reported that the leaf area index in foxtail millet increased significantly with increase in nitrogen dose from 25 kg N ha^{-1} to 50 kg N ha^{-1} on sandy loam soils of Tirupati, Andhra Pradesh.

Arshewar *et al*. (2018) recorded higher leaf area of pearlmillet with application of 75 kg N ha^{-1}, which was however comparable with that of 60 and 45 kg N ha^{-1} on clayey loam soils of Parbhani, Maharashtra.

Charate *et al.* (2018) observed significant increase in leaf area of little millet with application of 60 kg N ha^{-1} over 20 kg N ha^{-1}, but was however comparable with that of 40 kg N ha^{-1} on *alfisols* of Bengaluru, Karnataka.

2.2.1.3 Dry matter production

Basavarajappa *et al.* (2002) reported that in foxtail millet significantly higher dry matter production was obtained with application of 60 kg N ha^{-1} compared with that of 30 kg N ha^{-1} on shallow *alfisols* of Dharward, Karnataka.

Hasan *et al*. (2013) noticed numerical enhancement in dry matter accumulation plant^{-1} of foxtail millet with application of N_{20} P_{15} K_{10} kg ha^{-1}, but was however comparable with that of N_{30} P_{24} K_{15} and N_{40} P_{32} K_{20} kg ha^{-1} on sandy loam soils of Mymensingh, Bangladesh.

Application of 125 per cent of recommended dose of nitrogen (75 kg N ha^{-1}) to finger millet resulted in significantly higher dry matter accrual than with 100 per cent RDN (60 kg N ha^{-1}) on sandy loam soils of Jagdalpur, Chhattisgarh (Pradhan *et al.*, 2015).

Jyothi *et al*. (2016) reported that increase in nitrogen level from 0 to 50 kg ha^{-1} significantly enhanced the dry matter production of foxtail millet on sandy loam soils of Tirupati, Andhra Pradesh.

On clayey loam soils of Parbhani, Maharashtra dry matter production of pearlmillet was significantly higher with application of 75 kg N ha^{-1} than with 45 kg N ha^{-1}, but found to be on par with that of 60 kg N ha^{-1} (Arshewar *et al*., 2018).

Charate *et al.* (2018) reported that there was a significant increase in dry matter production of little millet on dryland *alfisols* of Bengaluru, Karnataka with application of 60 kg N ha^{-1} compared to that of 20 kg N ha^{-1}, but was however comparable with that of 40 kg N ha^{-1}.

2.2.1.4 Number of tillers m^{-2}

Results of an experiment conducted on clay loam soils of Bursa, Turkey revealed that there was no significant difference in number of tillers m^{-2} in proso millet with increase in nitrogen level from 0 to 225 kg ha^{-1} (Turgut *et al*., 2006).

Significant increase in number of effective tillers plant^{-1} was not noticed with increase in nitrogen level from 0 to 40 kg ha^{-1} in foxtail millet on sandy loam soils of Mymensingh, Bangladesh (Hasan *et al*., 2013).

Significantly higher number of tillers m^{-2} was recorded in kodo millet with application of 40 kg N ha^{-1} compared to that of 20 kg N ha^{-1}on sandy loam soils at Rewa, Madhya Pradesh (Singh and Maurya, 2013).

Maximum number of productive tillers $plant^{-1}$ was observed in barnyard millet with application of 40 kg N ha^{-1} than with 20 kg N ha^{-1} on sandy clay loam soils at Ranichauri, Uttarakhand (Yadav and Yadav, 2013).

Pradhan *et al*. (2015) recorded significantly more number of effective tillers m^{-2} of finger millet on sandy loam soils at Jagdalpur, Chhattisgarh with application of 125 per cent of recommended dose of nitrogen (75 kg N ha^{-1}) than with 75 per cent RDN (45 kg N ha^{-1}) but was however, comparable with that of 100 per cent RDN (60 kg N ha^{-1}).

Significant increase in number of tillers m^{-2} of foxtail millet was observed with the application of 50 kg N ha^{-1} than with 25 kg N ha^{-1} on sandy loam soils of Tirupati, Andhra Pradesh (Jyothi *et al*., 2016).

Application of 75 kg N ha^{-1} resulted in significantly higher number of tillers $plant^{-1}$ of pearlmillet than that with 45 kg N ha^{-1}, but was however on par with that of 60 kg N ha^{-1} on clayey loam soils of Parbhani, Maharashtra (Arshewar *et al*., 2018).

Number of tillers m^{-2} of little millet with application of 60 kg N ha^{-1} was comparable with that of 40 kg N ha^{-1} on dryland *alfisols* of Bengaluru, Karnataka (Charate *et al.*, 2018).

2.2.1.5 Days to 50 per cent flowering

Yadav and Yadav (2013) observed that in barnyard millet number of days to 50 per cent flowering was minimum with application of 100 per cent recommended dose of nutrients (40:20:20 NPK kg ha^{-1}), while the maximum number of days to 50 per cent flowering was with control on sandy loam soils of Ranichauri, Uttarakhand.

2.2.1.6 Days to maturity

Jyothi *et al.* (2016) reported that in foxtail millet the number of days to maturity reduced significantly with increase in nitrogen dose from 25 to 50 kg N ha^{-1} on sandy loam soils of Tirupati, Andhra Pradesh.

2.2.2 Yield Attributes

2.2.2.1 Number of panicles m^{-2}

Singh and Maurya (2013) noticed consistent increase in number of panicles m^{-2} of kodo millet with increase in nitrogen level from 0 to 40 kg ha^{-1} on sandy loam soils at Rewa, Madhya Pradesh.

Arshewar *et al.* (2018) observed significantly more number of ear heads $plant^{-1}$ of pearlmillet with application of 75 kg N ha^{-1} compared to that of 60 kg N ha^{-1} on clayey loam soils of Parbhani, Maharashtra.

2.2.2.2 Length of the panicle

Increase in nitrogen level from 0 to 30 kg ha^{-1} resulted in significant increase in panicle length of foxtail millet on sandy loam soils at Mymensingh, Bangladesh (Hasan *et al.*, 2013).

Yadav and Yadav (2013) inferred that maximum panicle length of barnyard millet was noticed when the crop was fertilized with 100 per cent recommended dose of nutrient (40:20:20 NPK kg ha^{-1}) on silty clay loam soils of Ranichauri, Uttarakhand.

Significantly lengthier panicles of finger millet were observed with the application of 125 per cent of recommended dose of nitrogen (75 kg N ha^{-1}) compared with that of 75 per cent RDN (45 kg N ha^{-1}), but was found to be comparable with that of 100 per cent RDN (60 kg N ha^{-1}) on sandy loam soils of Jagdalpur, Chhattisgarh (Pradhan *et al.*, 2015).

Charate *et al.* (2018) observed significant increase in panicle length of little millet with application of 60 kg N ha^{-1} than with 20 kg N ha^{-1} and was however, comparable with that of 40 kg N ha^{-1} on *alfisols* of Bengaluru, Karnataka.

2.2.2.3 Weight of grains panicle^{-1}

Significantly higher panicle weight of foxtail millet was noticed with application of 60 kg N ha^{-1} compared with that of 30 kg N ha^{-1} on shallow *alfisols* of Dharward, Karnataka (Basavarajappa *et al.*, 2002).

Barnyard millet was reported to produce comparable grain weight panicle^{-1} with 100 per cent recommended dose of nutrients (40:20:20 NPK kg ha^{-1}) and 75 per cent RDN on sandy clay loam soils of Ranichauri, Uttarakhand (Yadav and Yadav, 2013).

On clayey loam soils of Parbhani, Maharashtra, significantly higher ear head weight of pearlmillet was recorded with application of 75 kg N ha^{-1} compared with that of 45 kg N ha^{-1}, but was found to be on par with that of 60 kg N ha^{-1} (Arshewar *et al.*, 2018).

Application of 40 kg N ha^{-1} to little millet resulted in significantly more grain weight per panicle compared to that with 20 kg N ha^{-1} on dryland *alfisols* of Bengaluru, Karnataka (Charate *et al.*, 2018).

2.2.2.4 1000 grain weight

Basavarajappa *et al.* (2002) stated that 1000 grain weight of foxtail millet increased with increase in nitrogen level from 0 to 60 kg ha^{-1} on shallow *alfisols* of Dharward, Karnataka.

No significant difference was noticed by Hasan *et al.* (2013) in 1000 grain weight of *kharif* foxtail millet with increase in nitrogen levels from 0 to 40 kg ha^{-1} on sandy loam soils of Mymensingh, Bangladesh.

On sandy loam soils of Rewa, Madhya Pradesh, application of 40 kg N ha^{-1} resulted in significantly higher 1000 grain weight of kodo millet than with that of control (Singh and Maurya, 2013).

Maximum 1000 grain weight of barnyard millet was recorded with application of 40:20:20 kg NPK ha^{-1} on sandy clay loam soils of Ranichauri, Uttarakhand (Yadav and Yadav, 2013).

Increase in nitrogen level from 20 to 80 kg ha^{-1} could not significantly influence the test weight of white ragi varieties on vertisols of Nandyal, Andhra Pradesh (Munirathnam and Kumar, 2015).

Higher test weight of finger millet was recorded with application of 125 per cent of recommended dose of nitrogen (75 kg N ha^{-1}), but was however comparable with that of 100 per cent RDN (60 kg N ha^{-1}) on sandy loam soils of Jagdalpur, Chhattisgarh (Pradhan *et al*., 2015).

2.2.3 Yield

2.2.3.1. Grain yield

Significantly higher grain yield of pearlmillet was registered with application of 90 kg N ha^{-1} compared with that of 60 kg N ha^{-1} on loamy sand soils of Jaipur, Rajasthan (Sharma *et al*., 1999).

Basavarajappa *et al*. (2002) reported that comparable grain yield of foxtail millet was recorded with application of 60 and 30 kg N ha^{-1} on shallow *alfisols* of Dharward, Karnataka.

Significantly higher grain yield of finger millet was resulted with application of 120 kg N ha^{-1} compared with that of 60 kg N ha^{-1}, but was found to be on par with that of 90 kg N ha^{-1}on clayey soils of Junagadh, Gujarat (Jadhav *et al*., 2011).

Higher grain yield of foxtail millet was realized with application of 30 kg N ha^{-1} which was however, on par with that of 20 kg N ha^{-1} on sandy loam soils of Mymensingh, Bangladesh (Hasan *et al*., 2013).

Munirathnam and Kumar (2015) reported that higher grain yield of white ragi varieties was obtained with application of 80 kg N ha^{-1}, which was however statistically on par with that of 60 kg N ha^{-1} but was significantly superior over 40 kg N ha^{-1} on vertisols of Nandyal, Andhra Pradesh.

Pradhan *et al*. (2015) recorded higher grain yield of finger millet with application of 125 per cent of recommended dose of nitrogen (75 kg N ha^{-1}), which was however statistically comparable with that of 75 per cent (45 kg N ha^{-1}) and 100 per cent RDN (60 kg N ha^{-1}) on sandy loam soils of Jagdalpur, Chhattisgarh.

Significant increase in grain yield of foxtail millet was observed with application of 50 kg N ha^{-1} than with 25 kg N ha^{-1} on sandy loam soils of Tirupati, Andhra Pradesh (Jyothi *et al*., 2016).

Arshewar *et al*. (2018) recorded comparable grain yields of pearlmillet with application of 75 kg N ha^{-1} and 60 kg N ha^{-1} on clayey loam soils of Parbhani, Maharashtra.

Application of 60 kg N ha^{-1} resulted in significantly higher grain yield of little millet over 20 kg N ha^{-1}, but was comparable with that of 40 kg N ha^{-1} on dryland *alfisols* of Bengaluru, Karnataka (Charate *et al*., 2018).

2.2.3.2 Straw yield

Sharma *et al*. (1999) obtained significantly higher stover yield of pearlmillet with application of 90 kg N ha^{-1} than with that of 30 kg N ha^{-1}, but was however on par with that of 60 kg N ha^{-1} on loamy sand soils of Jaipur, Rajasthan.

On clay soils of Junagadh, Gujarat significantly higher straw yield of finger millet was recorded with application of 120 kg N ha^{-1} over 60 kg N ha^{-1}, but was however comparable with that of 90 kg N ha^{-1} (Jadhav *et al*., 2011).

Application of 100 per cent RDF (40:20:20 NPK kg ha^{-1}) was reported to give significantly higher straw yield of barnyard millet than with that of 75 per cent RDF (30:15:15 NPK kg ha^{-1}) on sandy clay loam soils of Ranichauri, Uttarakhand (Yadav and Yadav, 2013).

Munirathnam and Kumar (2015) reported that significantly higher straw yield of white ragi was obtained with application of 80 kg N ha^{-1} than that with 40 kg N ha^{-1}, but the former was however on par with that of 60 kg N ha^{-1} on vertisols of Nandyal, Andhra Pradesh during *kharif*.

Comparable straw yields of finger millet was observed with application of 125 per cent of recommended dose of nitrogen (75 kg N ha^{-1}) and 100 per cent RDN (60 kg N ha^{-1}) on sandy loam soils at Jagdalpur, Chhattisgarh (Pradhan *et al*., 2015).

Among the nitrogen levels tried, *kharif* sown foxtail millet resulted in significant increase of straw yield with application of 50 kg N ha^{-1} compared with that of 25 kg N ha^{-1} on sandy loam soils of Tirupati, Andhra Pradesh (Jyothi *et al*., 2016).

Charate *et al.* (2018) observed comparable straw yields of little millet with application of 60 kg N ha^{-1} and 40 kg N ha^{-1} on dryland *alfisols* of Bengaluru, Karnataka.

2.2.4 Post Harvest Soil Nutrient Status

Jyothi *et al*., (2016) reported that on sandy loam soils of Tirupati, Andhra Pradesh application of 50 kg N ha^{-1} to foxtail millet resulted in significantly higher post harvest soil available nitrogen, phosphorus and potassium compared with that of 25 kg N ha^{-1}.

Kiranmai (2015) recorded highest post harvest soil available N with application of 120 kg ha^{-1} and highest post harvest soil available P_2O_5 and K_2O with 60 kg N ha^{-1} in finger millet on sandy loam soils of Tirupati, Andhra Pradesh.

2.2.5 Nutrient Uptake at Harvest

Basavarajappa *et al.* (2002) recorded significantly higher NPK uptake by foxtail millet with application of 60 kg N ha^{-1} than with 30 kg N ha^{-1} on shallow *alfisols* at Dharward, Karnataka.

Jadhav *et al*. (2011) stated that significantly higher NPK uptake by pearlmillet was recorded with application of 120 kg N ha^{-1} on clayey soils of Junagadh, Gujarat.

Significantly higher uptake of NPK by foxtail millet was recorded with application of 50 kg N ha^{-1} than with that of 25 kg N ha^{-1} on sandy loam soils of Tirupati, Andhra Pradesh (Jyothi *et al*., 2016).

2.2.6 Economics

Singh and Maurya (2013) revealed that in kodo millet application of 40 kg N ha^{-1} resulted in highest net returns and benefit:cost ratio on sandy loam soils of Rewa, Madhya Pradesh.

Maximum gross returns, net returns and benefit:cost ratio of white ragi was realized with application of 80 kg N ha^{-1} on vertisols of Nandyal, Andhra Pradesh (Munirathnam and Kumar, 2015).

On sandy loam soils of Tirupati, Andhra Pradesh, *kharif* foxtail millet provided with 50 kg N ha^{-1} resulted in higher gross returns, net returns and benefit:cost ratio than with 25 kg N ha^{-1} (Jyothi *et al*., 2016).

Arshewar *et al*. (2018) obtained maximum gross and net returns with application of 75 kg N ha^{-1} to pearlmillet closely followed by that with 60 kg N ha^{-1} on clayey loam soils of Parbhani, Maharashtra.

Chapter – III

Material and Methods

Chapter III

MATERIAL AND METHODS

The present research entitled **"Performance of proso millet under varied times of sowing and levels of nitrogen"** was conducted during *kharif*, 2019. During the period of study, the material used and methods followed are presented hereunder.

3.1 LOCATION OF THE EXPERIMENTAL SITE

The field experiment was carried out in Field No. 40 of Dryland Farm, S. V. Agricultural College, Tirupati campus of Acharya N. G. Ranga Agricultural University which is geographically situated at 13.5^{o} N latitude, 79.5^{o} E longitude, with an altitude of 182.9 m above the mean sea level in the Southern Agro-climatic Zone of Andhra Pradesh.

3.2 WEATHER DURING THE CROP GROWTH PEROID

The weather that prevailed during the crop growth period (26-06-2019 to 17-10-2019) recorded at Meteorological Observatory, S. V. Agricultural College, Tirupati is presented in Table 3.1 and depicted in Fig. 3.1.

The weekly mean maximum temperature during the crop growth period ranged from 29.0^{0}C to 38.1^{0}C with an average of 33.9^{0}C. The decennial mean maximum temperature for the corresponding period ranged from 32.7^{0}C to 36.8^{0}C with an average of 34.4^{0}C. The weekly mean minimum temperature during the crop growth period ranged from 21.8^{0}C to 28.5^{0}C with an average of 25.2^{0}C, whereas the decennial weekly mean minimum temperature for the corresponding period ranged from 22.5^{0}C to 26.3^{0}C with an average of 24.8^{0}C.

The weekly mean relative humidity during the crop growth period ranged from 45.9 to 86.7 per cent with an average of 66.2 per cent, while the

Table 3.1. Standard week wise meteorological data during the crop growth period of proso millet (26.06.2019 to 17.10.2019)

Standard week	Date and Month	Temperature (°C)				Relative humidity (%)		Rainfall (mm)		Number of rainy days		Evaporation (mm day^{-1})		Bright sunshine (hours day^{-1})	
		Maximum		Minimum											
		A	DN	A	DN	A	DN	A	DN	A	DN	A	DN	A	DN
26	25 June - 01 July	36.8	0.0	27.4	1.4	45.9	-6.9	48.2	28.0	2	0.5	6.4	-0.6	4.0	-0.3
27	02 July - 08 July	38.1	2.5	28.5	2.2	48.2	-7.7	1.4	-22.6	0	-1.4	7.9	1.0	4.0	-0.8
28	09 July - 15 July	36.9	2.8	25.6	-0.2	57.4	-0.5	33.0	5.9	3	1.3	6.5	-1.2	6.7	-3.1
29	16 July - 22 July	36.0	1.1	25.7	0.0	62.9	4.4	34.2	10.9	2	0.4	5.8	-1.1	4.4	-1.3
30	23 July - 29 July	34.2	-1.1	25.4	-0.3	64.7	7.2	24.8	2.7	2	0.4	4.2	-2.8	2.5	2.2
31	30 July- 05 Aug.	34.6	-0.5	26.5	0.4	57.8	1.1	2.0	-5.7	0	-0.9	5.2	-1.6	2.4	0.9
32	06 Aug.- 12 Aug.	35.8	0.4	27.6	1.8	56.4	-1.9	0.0	-24.9	0	-1.5	6.5	-0.8	3.9	0.5
33	13 Aug.- 19 Aug.	34.2	0.2	25.3	0.5	68.3	4.9	118	69.9	4	1.0	4.1	-1.3	3.2	0.9
34	20 Aug.- 26 Aug.	31.6	-2.5	23.8	-1.2	69.4	4.8	60.0	10.4	3	0.9	3.2	-2.8	4.6	0.2
35	27 Aug.- 02 Sep.	33.6	-0.2	24.9	0.5	70.4	5.3	33.2	2.6	4	2.2	3.5	-1.9	4.4	-0.8
36	03 Sep. - 09 Sep.	32.9	-0.8	24.3	-0.2	67.1	4.4	26.0	-13.8	3	1.3	3.3	-2.4	2.2	2.2
37	10 Sep. - 16 Sep.	33.1	-0.5	24.3	0.0	71.0	5.4	127.8	92.3	4	2.1	3.6	-1.1	6.1	-1.5
38	17 Sep. - 23 Sep.	30.4	-3.3	23.6	-0.9	85.4	20.7	94.6	66.7	4	2.3	2.0	-3.5	2.4	2.3
39	24 Sep. - 30 Sep.	31.4	-2.8	25.3	1.1	72.3	7.1	4.0	-23.4	1	-0.5	4.0	-1.3	5.1	0.0
40	01 Oct. - 07 Oct.	33.9	1.2	25.1	1.9	71.1	3.4	84.2	33.2	2	-0.2	5.3	0.4	8.8	-3.7
41	08 Oct. - 14 Oct.	33.5	-0.2	21.8	-1.3	70.7	5.1	25.8	-4.2	1	-0.7	5.2	0.4	8.5	-3.4
42	15 Oct. - 21 Oct.	29.0	-4.4	23.6	1.1	86.7	21.0	43.8	25.9	4	2.8	1.9	-2.9	3.2	2.4
Total rainfall (mm)								761.0		39					

A: Actual **DN: Deviation from decennial mean**

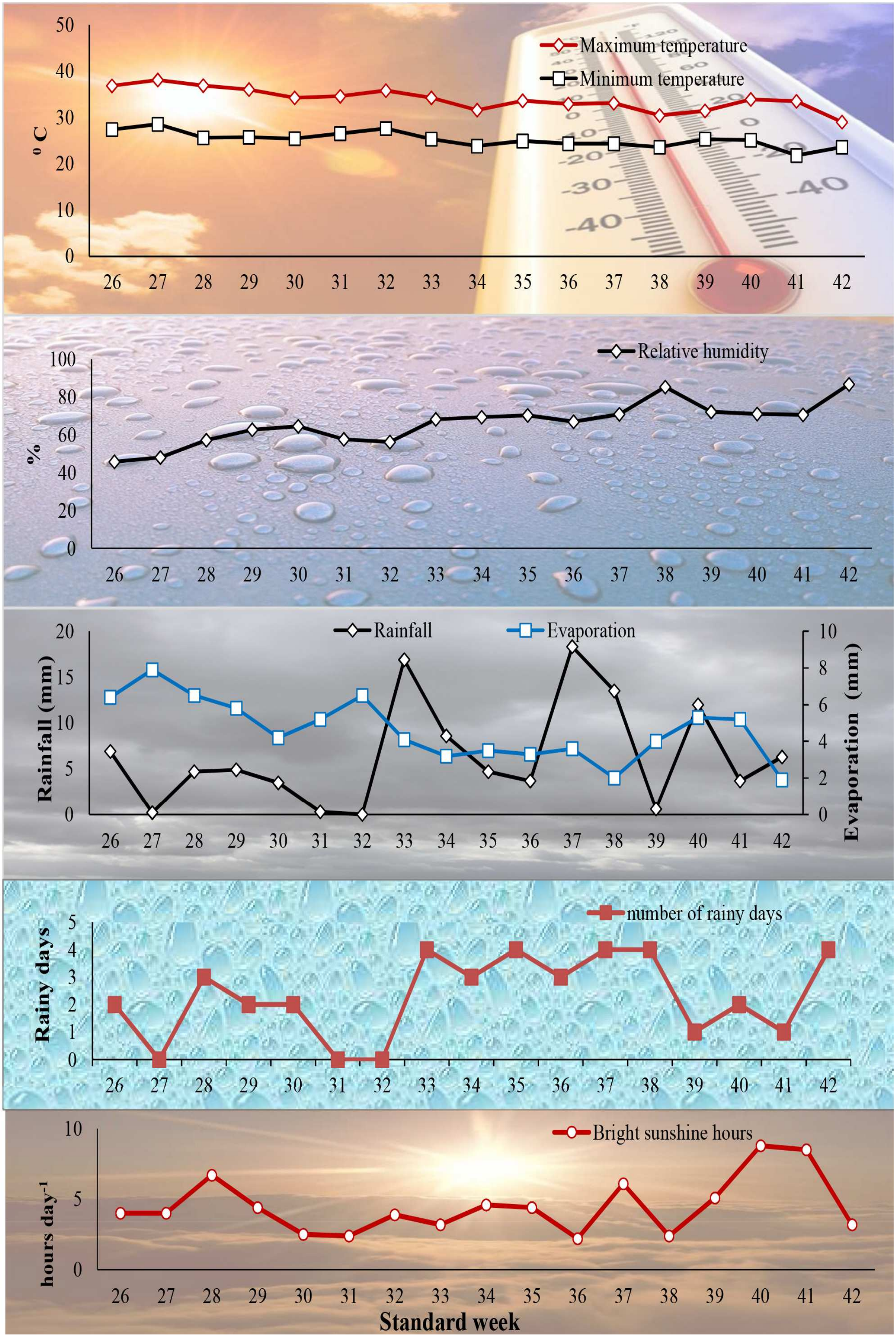

Fig. 3.1. Standard week wise meteorological data during the crop growth period of proso millet (26.6.2019 to 17.10.2019).

decennial mean for the corresponding period ranged from 52.8 to 67.7 per cent with an average of 61.6 per cent. The weekly mean bright sunshine hours day^{-1} during the crop growth period ranged from 2.2 to 8.8 with an average of 4.5, whereas the decennial mean for the corresponding period ranged from 0.1 to 12.5 with an average of 4.7 hours day^{-1}.

During the crop growth period, a total rainfall of 761 mm was received in 39 rainy days as against the decennial rainfall of 507 mm received in 29 rainy days for the corresponding period.

During the crop growth period, the weekly mean evaporation (USWB Class - A open pan evaporimeter) ranged from 1.9 to 7.9 mm day^{-1}, with an average of 4.6 mm day^{-1}, whereas the decennial mean for the corresponding period ranged from 4.7 to 7.7 mm day^{-1}, with an average of 6.0 mm day^{-1}.

3.3 SOIL CHARACTERISTICS OF THE EXPERIMENTAL FIELD

Soil samples from 0 to 30 cm depth were drawn at random from the experimental field and was analyzed for physico-chemical properties by following the standard methods and the results are furnished in Table 3.2.

Perusal of the data indicated that the soil was sandy loam in texture, neutral in soil reaction, low in organic carbon and available nitrogen, medium in available phosphorus and available potassium.

3.4 CROPPING HISTORY OF THE EXPERIMENTAL FIELD

The cropping history of the experimental field during three years preceding the present investigation is given below.

Year	***Kharif***	***Rabi***	**Summer**
2016-17	Crop museum	Groundnut	Fallow
2017-18	U. G. Student plots	Groundnut	Fallow
2018-19	Crop museum	Groundnut	Fodder cowpea
2019-20	**(Present experiment)**		

Table 3.2. Physico-chemical properties of the experimental field

S. No.	Particulars	Value	Method adopted
I.	**Physical characteristics**		
	Coarse sand (%)	50.0	Bouyoucos Hydrometer (Piper, 1966)
	Fine sand (%)	30.0	
	Silt (%)	5.0	
	Clay (%)	15.0	
	Soil texture	Sandy loam	
II.	**Chemical characteristics**		
	Soil pH (1:2.5 soil water suspension)	7.30	Glass electrode pH meter (Jackson, 1973)
	Electrical conductivity (dS m^{-1})	0.14	Conductivity bridge (Jackson, 1973)
	Organic carbon (%)	0.46	Wet digestion method (Walkley and Black, 1934)
	Available N (kg ha^{-1})	197.20	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
	Available P_2O_5 (kg ha^{-1})	38.10	Olsen's method (Olsen *et al.*, 1954)
	Available K_2O (kg ha^{-1})	274.40	Flame photometry method (Jackson, 1973)

3.5 EXPERIMENTAL DETAILS

3.5.1 Design and Layout

The experiment was laid out in a split-plot design with four main plots and four sub plots and replicated thrice. The layout plan of the experiment was depicted in Fig.3.2.

3.5.2 Treatments

Main plots: Times of sowing (4)

- S_1 : II Fortnight (FN) of June
- S_2 : I FN of July
- S_3 : II FN of July
- S_4 : I FN of August

Sub plots : Nitrogen levels (4)

- N_1 : Control
- N_2 : 20 kg ha^{-1}
- N_3 : 40 kg ha^{-1}
- N_4 : 60 kg ha^{-1}

R I	S_2N_1	S_2N_2	S_4N_3	S_4N_1	S_3N_3	S_3N_4	S_1N_1	S_1N_4
	S_2N_4	S_2N_3	S_4N_4	S_4N_2	S_3N_1	S_3N_2	S_1N_3	S_1N_2
	IRRIGATION CHANNEL							
R II	S_3N_1	S_3N_2	S_2N_1	S_2N_4	S_1N_2	S_1N_3	S_4N_4	S_4N_2
	S_3N_3	S_3N_4	S_2N_3	S_2N_2	S_1N_4	S_1N_1	S_4N_3	S_4N_1
	IRRIGATION CHANNEL							
R III	S_4N_4	S_4N_1	S_1N_4	S_1N_3	S_3N_1	S_3N_4	S_2N_1	S_2N_2
	S_4N_2	S_4N_3	S_1N_1	S_1N_2	S_3N_2	S_3N_3	S_2N_4	S_2N_3

4.0 m

5.0 m

Design : Split-plot
Replications : Three
Variety : DHPM-2769

Gross plot size : 5.0 m x 4.0 m
Net plot size : 3.5 m x 3.4 m
Spacing : 25 cm x 10 cm

Treatments :

Main plots : Times of sowing (4)
S_1 : II Fortnight (FN) of June
S_2 : I FN of July
S_3 : II FN of July
S_4 : I FN of August

Sub plots : Nitrogen levels (4)
N_1 : Control
N_2 : 20 kg ha^{-1}
N_3 : 40 kg ha^{-1}
N_4 : 60 kg ha^{-1}

Fig.3.2. Layout plan of the experimental field.

3.5.3 Plot Size

Gross Plot : 5.0 m × 4.0 m

Net Plot : 3.5 m × 3.4 m

3.5.4 Variety

The test variety of proso millet, DHPM-2769 was developed at AICRP on Small Millets, Dholi, Bihar and was released in the year, 2017. This variety is suitable for contingency planning and requires 70 - 72 days for maturity. It has an average yield potential of 23 to 25 q ha^{-1}.

3.6 CULTIVATION DETAILS

3.6.1 Field Preparation

The experimental field was ploughed twice with a tractor drawn cultivator followed by harrowing to obtain a good tilth. After levelling, plots and channels were formed and necessary micro levelling was done in each plot to take up sowing.

3.6.2 Seeds and Sowing

Healthy and matured seeds of high germination percentage was used for sowing. Seed @ 10 kg ha^{-1} was sown by mixing with sand and were placed at 2 cm depth in an open furrow and covered thoroughly. The spacing adopted was 25 cm × 10 cm.

Time of sowing	Date of sowing	Date of harvesting
II Fortnight (FN) of June	26-06-2019	12-09-2019
I FN of July	11-07-2019	24-09-2019
II FN of July	31-07-2019	11-10-2019
I FN of August	08-08-2019	17-10-2019

3.6.3 Thinning and Gap Filling

Thinning and gap filling was done at 10 DAS in the treatments in order to maintain optimum plant population retaining one healthy seedling $hill^{-1}$.

3.6.4 Fertilizer Application

Fertilizers were applied as per the treatments. Phosphorus was applied @ 20 kg ha^{-1} through single super phosphate to all the plots in common as basal. Nitrogen was applied as per the subplot treatments through urea where 50 per cent was applied as basal and the remaining half was top dressed at 20 DAS.

3.6.5 Irrigation

A total number of 3 irrigations were given, first at 3 DAS for better establishment, second at 20 DAS when nitrogen was applied as split dose and the last irrigation at 30-35 DAS.

3.6.6 Weed management

Two weedings were carried out, one at 25 DAS and the other at 40 DAS.

3.6.7 Plant Protection

Chlorpyriphos was sprayed against stem borer and hispa at 25 DAS @ 2 ml l^{-1} of water.

3.6.8 Harvesting and Threshing

The crop was harvested by cutting the plants close to the ground after attaining maturity. The plants from border rows and the net plots were harvested separately and the produce from each treatment were sundried sufficiently and threshed manually. The grain from each plot was sun dried on a threshing floor to a moisture level of 14 per cent. Straw was allowed to dry to a constant weight in the plots itself.

3.7 OBSERVATIONS

3.7.1 Pre-harvest Observations

Five plants were selected from each net plot at random and labelled with tags to record the growth parameters throughout the crop growing period.

3.7.1.1 Plant height

Plant height was recorded from five randomly selected plants of each net plot at 20, 40, 60 DAS and at harvest by measuring from the base of the stem to the tip of the top most leaf at 20 and 40 DAS and to the panicle tip at 60 DAS and at harvest, averaged and expressed in cm.

3.7.1.2 Leaf area index

Five destructively sampled plants from the border rows of the plot were taken at 20, 40, 60 DAS and at harvest to measure leaf area by using Li-COR model, LT-300 leaf area meter with transparent conveyor belt and electronic display and expressed in cm^2 $plant^{-1}$. Leaf area index was calculated by dividing leaf area with corresponding land area as suggested by Watson (1952).

$$\text{LAI}=\frac{\text{Total leaf area}}{\text{Unit land area}}$$

3.7.1.3 Dry matter production

Five plants collected for leaf area estimation at 20, 40, 60 DAS and at harvest were used for estimation of DMP. These samples were air dried and then oven dried at 65°C till their constant weights were obtained, averaged and expressed in kg ha^{-1}.

3.7.1.4 Number of tillers m^{-2}

The number of tillers were counted from one square meter area of net plot at 20, 40, 60 DAS and at harvest and averaged to compute number of tillers m^{-2}.

3.7.1.5 Days to 50 per cent flowering

The crop was considered to have reached 50 per cent flowering when 50 per cent of plants attained flowering in each plot.

3.7.1.6 Days to maturity

The number of days from sowing to the date when physiological maturity attained was considered as days to maturity.

3.7.2 Post-harvest Observations

3.7.2.1 Number of panicles m^{-2}

Number of panicles were counted from one square meter area of net plot in each treatment, averaged and expressed as number of panicles m^{-2}.

3.7.2.2 Length of the panicle

The length of the panicle from the tagged plants were measured from the base of the panicle to the tip of panicle and the mean length was arrived and expressed in cm.

3.7.2.3 Weight of grains panicle^{-1}

The weight of grains panicle^{-1} was recorded from the tagged plants for each treatment and the average was calculated and expressed as weight of grains panicle^{-1}.

3.7.2.4 1000 grain weight

A representative sample of grains from the net plot yield was taken out of which 1000 grains were counted, weighed and expressed in g.

3.7.2.5 Grain yield

The grain obtained after threshing the produce from each of the net plot was sundried, weighed and expressed in kg ha^{-1}.

3.7.2.6 Straw yield

The straw obtained from the net plot was weighed after thorough sun drying to a constant weight and expressed in kg ha^{-1}.

3.8 POST HARVEST SOIL NUTRIENT STATUS

Immediately after harvesting of the crop, soil samples were collected from each plot, shade dried, sieved and analysed for available nitrogen (Subbiah and Asija, 1956), available phosphorus (Olsen *et al.*, 1954) and available potassium (Jackson, 1973) by following the standard procedures as outlined in Table 3.2.

3.9 NUTRIENT UPTAKE

For estimation of nitrogen, phosphorus and potassium in plants, well dried plant samples collected for dry matter production were used. Samples from each plot were oven dried, powdered and used for chemical analysis.

3.9.1 Nitrogen Uptake

Nitrogen content in the dry matter was estimated using microkjeldahl method (AOAC, 1990). The nitrogen uptake was calculated by multiplying the nitrogen content with the corresponding dry matter production and expressed in kg ha^{-1}.

3.9.2 Phosphorus Uptake

The plant samples were digested with di-acid and analysed for phosphorus content by vanado–molybdo phosphoric acid yellow colour method (Jackson, 1973). The intensity of yellow colour developed was recorded using Spectronic-20 D. The phosphorus uptake was calculated by multiplying the phosphorus content with the respective dry matter production and expressed in kg ha^{-1}.

3.9.3 Potassium Uptake

Potassium content of the di-acid digested extract was determined using ELICO flame photometer and the uptake was calculated by multiplying the potassium content with the corresponding dry matter production and expressed in kg ha^{-1}.

3.10 ECONOMICS

The total cost of cultivation (₹ ha^{-1}) was calculated for each treatment based on the cost of inputs. Gross monetary returns (₹ ha^{-1}) were arrived at by multiplying economic yield with the prevailing market price of proso millet grain and straw. Net monetary returns (₹ ha^{-1}) were arrived by deducting the cost of cultivation from gross monetary returns for the corresponding treatments. Benefit:cost ratio was worked out by using the following formula.

$$\text{Benefit:cost ratio} = \frac{\text{Gross returns}\left(₹\ \text{ha}^{-1}\right)}{\text{Cost of cultivation}\left(₹\ \text{ha}^{-1}\right)}$$

3.11 STATISTICAL ANALYSIS

The data recorded on various parameters of crop were analyzed statistically following the analysis of variance for split-plot design as suggested by Panse and Sukhatme (1985). Wherever the treatment differences were found significant (‘F’ test), critical difference was worked out at 5 % level of probability and the values were furnished. Treatmental differences that were not significant were denoted by “NS”.

Chapter – IV

Results & Discussion

Chapter IV

RESULTS AND DISCUSSION

The results of the experiment entitled **"Performance of proso millet [*Panicum miliaceum* (L.)] under varied times of sowing and levels of nitrogen"** conducted during *kharif*, 2019 on sandy loam soils of dryland farm at S.V. Agricultural College, Tirupati campus of Acharya N.G. Ranga Agricultural University are presented in this chapter. The experimental data were statistically analysed, apportioned under various heads, sub-heads and furnished in tables and illustrated wherever necessary.

4.1 WEATHER

The weather conditions were within the favourable limits during the crop growth period of proso millet sown during II FN of June, however slight variation was observed in few weather parameters when sowing was extended upto I FN of August. The insight into the prevailed weather conditions indicated that the weather variables were within the cardinal range so as to enable the crop to reasonably express the effect of imposed treatments.

4.2 GROWTH PARAMETERS

4.2.1 Plant Height

Plant height increased progressively with advance in age of the crop. Times of sowing and varied levels of nitrogen significantly influenced the plant height (Table 4.1 and Fig. 4.1) at 20, 40, 60 DAS and at harvest. While the interaction effect of times of sowing and varied levels of nitrogen was found to be non significant.

4.2.1.1 Plant height at 20 DAS

The crop sown during II FN of June (S_1) resulted in taller plants which was however comparable with that of I FN of July (S_2). The latter was found to be significantly superior to that of II FN of July (S_3) sown crop. Significantly shorter plants were with the crop sown during I FN of August (S_4).

Table 4.1. Plant height of proso millet at different growth stages as influenced by times of sowing and nitrogen levels

Treatments	Plant height (cm)			
	20 DAS	**40 DAS**	**60 DAS**	**At harvest**
Times of Sowing (S)				
S_1 - II FN of June	28.6	76.0	89.0	92.0
S_2 - I FN of July	28.0	68.0	80.0	86.0
S_3 - II FN of July	25.9	57.2	73.0	77.0
S_4 - I FN of August	11.8	50.3	62.0	66.0
SEm±	0.31	1.74	2.01	1.21
CD (P=0.05)	1.1	6.1	7.2	4.1
Nitrogen levels (N)				
N_1 –Control	20.9	53.0	64.0	68.0
N_2 - 20 kg ha^{-1}	22.3	60.0	72.0	76.0
N_3 - 40 kg ha^{-1}	24.8	63.0	80.0	86.0
N_4 - 60 kg ha^{-1}	26.4	73.0	87.0	91.0
SEm±	0.37	1.04	1.11	1.02
CD (P=0.05)	1.1	3.1	3.1	3.0
Times of sowing (S) x Nitrogen levels (N)				
N at S				
SEm±	0.61	3.42	3.91	2.42
CD (P=0.05)	NS	NS	NS	NS
S at N				
SEm±	0.71	2.46	2.71	2.17
CD (P=0.05)	NS	NS	NS	NS

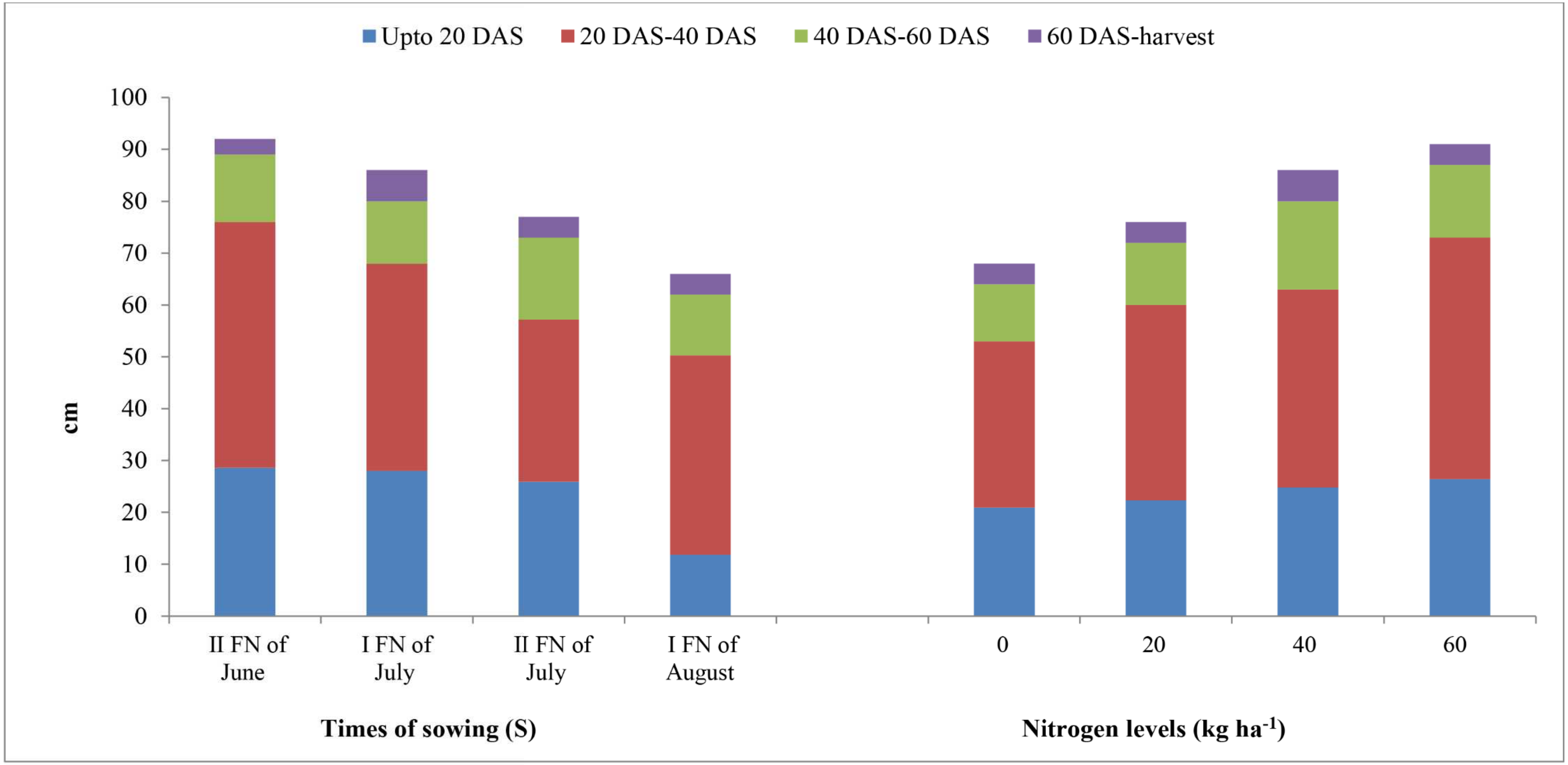

Fig. 4.1. Plant height (cm) of proso millet at different growth stages as influenced by times of sowing and nitrogen levels.

Application of 60 kg N ha^{-1} (N_4) resulted in higher plant height of proso millet than with 40 kg N ha^{-1} (N_3) and 20 kg N ha^{-1} (N_2) with significant disparity between any two of them. Significantly shorter plants were with control (N_1).

4.2.1.2 Plant height at 40 DAS

The earliest sown proso millet *i.e.* during II FN of June (S_1) produced significantly taller plants than that of I FN of July (S_2) and II FN of July (S_3). Difference in plant height due to latter two sowing times was also found to be significant. The lowest plant height was with I FN of August (S_4) sown crop.

Significantly taller plants of proso millet were noticed with application of 60 kg N ha^{-1} (N_4). The next best treatment was 40 kg N ha^{-1} (N_3) which was however comparable with that of 20 kg N ha^{-1} (N_2). The latter was inturn significantly superior to that of control (N_1), which recorded the lowest plant height.

4.2.1.3 Plant height at 60 DAS

Proso millet sown during II FN of June (S_1) resulted in significantly taller plants than with I FN of July (S_2) and II FN of July (S_3) sown crop. However, the latter two sowing times were comparable with each other. Crop sown during I FN of August (S_4) produced significantly shorter plants.

Application of 60 kg N ha^{-1} (N_4) to proso millet resulted in taller plants than with 40 kg N ha^{-1} (N_3), 20 kg N ha^{-1} (N_2) and control (N_1) with significant disparity between any two of the four nitrogen levels tried.

4.2.1.4 Plant height at harvest

Proso millet sown during II FN of June (S_1) resulted in significantly taller plants than with the other two later sown crops. Differences in plant height due to I FN of July (S_2) and II FN of July (S_3) sown crop was also significant. The shortest plants were recorded with I FN of August (S_4) sown crop.

Application of 60 kg N ha^{-1} (N_4) produced significantly taller plants of proso millet than with 40 kg N ha^{-1} (N_3) which inturn showed significant disparity with application of 20 kg N ha^{-1} (N_2). Significantly shorter plants were noticed with control (N_1).

Taller plants observed with II FN of June (S_1) sown crop at all the stages of sampling might be due to favourable climatic conditions during the crop growth period, resulting in higher rate of photosynthesis which directly influenced the plant height. These results were similar with the findings of Deshmukh *et al*. (2013), Mubeena *et al*. (2019) and Nandini and Sridhara (2019).

At all the stages of observation (20, 40, 60 DAS and at harvest), taller plants were observed with 60 kg N ha^{-1} (N_4) compared to the lower doses. Increase in plant height with increased supply of nitrogen might be attributed to the role of nitrogen in enhancing cell multiplication, cell elongation as well as maintenance of higher auxin levels. These results are compatible with the findings of Singh and Maurya (2013), Pradhan *et al*. (2015), Arshewar *et al*. (2018) and Charate *et al*. (2018).

4.2.2 Leaf Area Index (LAI)

Times of sowing and levels of nitrogen significantly influenced the leaf area index of proso millet [Table 4.2, Fig. 4.2 (a) and Fig. 4.2 (b)] at all the growth stages, while their interaction was not statistically traceable at any of the crop growth stage.

4.2.2.1 Leaf area index at 20 DAS

Higher leaf area index was with early sown crop *i.e*. during II FN of June (S_1) which was however comparable with that of I FN of July (S_2) sown crop. The leaf area index with I FN of July (S_2) sown crop was significantly higher than that of II FN of July (S_3). Significantly lower leaf area index was with the crop sown during I FN of August (S_4).

Application of 60 kg N ha^{-1} (N_4) to proso millet resulted in significantly more leaf area index than with 40 kg N ha^{-1} (N_3). The next best nitrogen level was 20 kg N ha^{-1} (N_2) which was significantly superior to control (N_1) but was however on par with that of 40 kg N ha^{-1} (N_3).

Table 4.2. Leaf area index of proso millet at different growth stages as influenced by times of sowing and nitrogen levels

Treatments	Leaf area index			
	20 DAS	40 DAS	60 DAS	At harvest
Times of Sowing (S)				
S_1 - II FN of June	0.12	0.75	1.14	1.05
S_2 - I FN of July	0.11	0.66	1.08	0.97
S_3 - II FN of July	0.09	0.60	1.02	0.90
S_4 - I FN of August	0.07	0.54	0.97	0.83
SEm±	0.002	0.013	0.011	0.014
CD (P=0.05)	0.01	0.04	0.04	0.05
Nitrogen levels (N)				
N_1 - Control	0.07	0.45	0.88	0.77
N_2 - 20 kg ha^{-1}	0.09	0.58	1.04	0.93
N_3 - 40 kg ha^{-1}	0.10	0.73	1.11	1.00
N_4 - 60 kg ha^{-1}	0.13	0.79	1.17	1.06
SEm±	0.002	0.014	0.016	0.017
CD (P=0.05)	0.01	0.04	0.05	0.05
Times of sowing (S) x Nitrogen levels (N)				
N at S				
SEm±	0.004	0.025	0.022	0.027
CD (P=0.05)	NS	NS	NS	NS
S at N				
SEm±	0.004	0.027	0.029	0.032
CD (P=0.05)	NS	NS	NS	NS

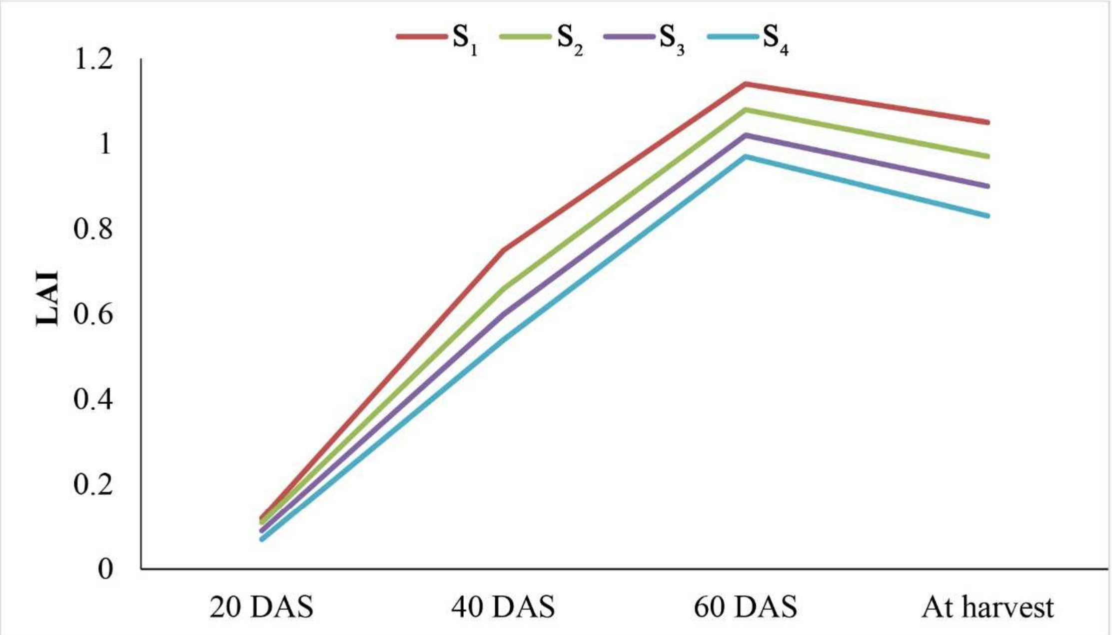

Fig. 4.2 (a). Leaf area index of proso millet at different growth stages as influenced by times of sowing.

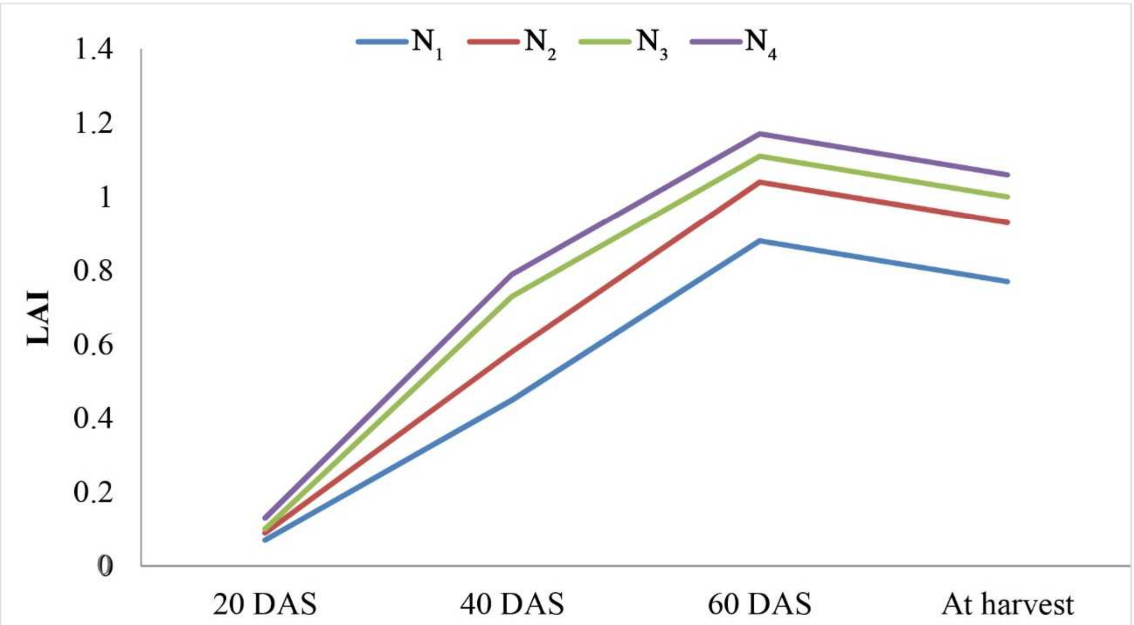

Fig. 4.2 (b). Leaf area index of proso millet at different growth stages as influenced by nitrogen levels.

4.2.2.2 Leaf area index at 40 DAS

Higher leaf area index of proso millet was recorded when sowing was done during II FN of June (S_1) which was significantly superior to that of I FN of July (S_2) and II FN of July (S_3). Difference between the two latter sown crops was also significant. The lowest leaf area index was with I FN of August (S_4) sown crop.

Among the nitrogen levels tried, the highest leaf area index was with application of 60 kg N ha^{-1} (N_4) followed by that with 40 kg N ha^{-1} (N_3) and 20 kg N ha^{-1} (N_2) with significant disparity between any two of them. Significantly lower leaf area index was noticed with no nitrogen (N_1) application.

4.2.2.3 Leaf area index at 60 DAS

Significantly higher leaf area index of proso millet was recorded when the crop was sown during II FN of June (S_1). The next best sowing time was I FN of July (S_2) which was significantly superior to that of II FN of July (S_3). Crop sown during I FN of August (S_4) resulted in significantly lower leaf area index.

Application of 60 kg N ha^{-1} (N_4) resulted in higher leaf area index of proso millet followed by that with 40 kg N ha^{-1} (N_3) and 20 kg N ha^{-1} (N_2) with significant disparity between any two of them. Significantly lower leaf area index was realized with control (N_1).

4.2.2.4 Leaf area index at harvest

Higher leaf area index of proso millet was recorded when sowing was done during II FN of June (S_1) which was significantly superior to that of I FN July (S_2). Significantly lower leaf area index was recorded when the crop was sown during I FN of August (S_4) than with II FN of July (S_3).

The higher leaf area index was with the crop that received 60 kg N ha^{-1} (N_4) which was significantly higher than with other lower doses of nitrogen. Differences in leaf area index due to 40 kg N ha^{-1} (N_3) and 20 kg N ha^{-1} (N_2) was also significant and the lowest leaf area index was recorded with no nitrogen (N_1) application.

At all the growth stages, significantly higher leaf area index was with the crop sown during II FN of June (S_1). Early sown crop had prolonged vegetative lag phase which decreased gradually with delay in sowing from II FN of June (S_1) to I FN of August (S_4). Longer vegetative phase has the advantage of utilizing growth resources for a longer period and led to improved growth parameters including leaf area. Similar findings were reported by Deshmukh *et al.* (2013) and Siddig *et al.* (2013).

Increase in leaf area with increase in nitrogen dose at all the samplings was evidently due to increase in rate of leaf expansion and number of leaves tiller^{-1} coupled with involvement of nitrogen in chlorophyll formation which is main source of photosynthesis. Enhanced leaf area index with increased nitrogen level as resulted from this work validates with the findings of Mhaskar *et al.* (2005), Pradhan *et al.* (2015), Jyothi *et al.* (2016) and Charate *et al.* (2018).

4.2.3 Dry Matter Production

Dry matter production of proso millet increased progressively from sowing to the harvest irrespective of the treatments. Dry matter production as influenced by times of sowing and nitrogen levels was significant (Table 4.3 and Fig. 4.3). However, their interaction was not statistically traceable.

4.2.3.1 Dry matter production at 20 DAS

Dry matter accumulation of proso millet with II FN of June (S_1) and I FN of July (S_2) sown crops was comparable with each other. The latter sown crop during I FN of July (S_2) produced significantly higher dry matter than with II FN of July (S_3). The lowest dry matter production was with the crop sown during I FN of August (S_4).

Among the nitrogen levels tried, application of 60 kg N ha^{-1} (N_4) resulted in higher dry mater accumulation which was significantly higher than that with 40 kg N ha^{-1} (N_3) and 20 kg N ha^{-1} (N_2). Difference in dry matter production due to the latter two levels of nitrogen was also found to be significant. The lowest dry matter production was with control (N_1).

Table 4.3. Dry matter production of proso millet at different growth stages as influenced by times of sowing and nitrogen levels

Treatments	Dry matter production (kg ha^{-1})			
	20 DAS	40 DAS	60 DAS	At harvest
Times of Sowing (S)				
S_1 - II FN of June	81	1701	3829	4577
S_2 - I FN of July	79	1541	3307	4203
S_3 - II FN of July	69	1358	3088	3757
S_4 - I FN of August	64	1097	2862	3222
SEm±	1.1	35.0	60.5	73.4
CD (P=0.05)	4	123	214	259
Nitrogen levels (N)				
N_1 - Control	63	1181	2388	2923
N_2 - 20 kg ha^{-1}	73	1291	3238	3744
N_3 - 40 kg ha^{-1}	76	1511	3543	4255
N_4 - 60 kg ha^{-1}	81	1715	3918	4840
SEm±	0.8	36.0	81.9	99.9
CD (P=0.05)	2	106	241	293
Times of sowing (S) x **Nitrogen levels (N)**				
N at S				
SEm±	2.2	69.9	121.0	146.8
CD (P=0.05)	NS	NS	NS	NS
S at N				
SEm±	1.8	71.5	154.3	187.9
CD (P=0.05)	NS	NS	NS	NS

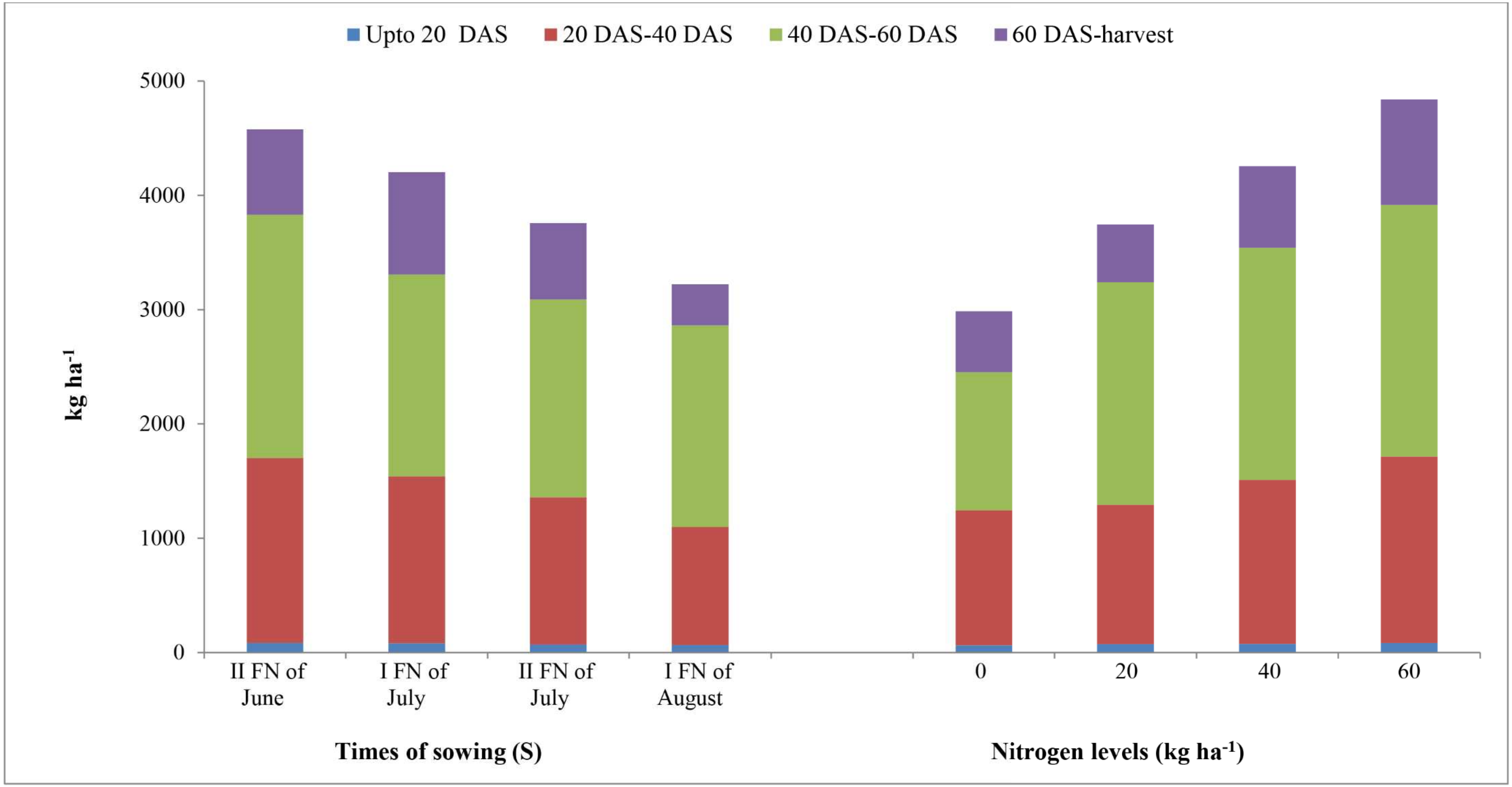

Fig. 4.3. Dry matter production (kg ha^{-1}) of proso millet at different growth stages as influenced by times of sowing and nitrogen levels.

4.2.3.2 Dry matter production at 40 DAS

Significantly higher dry matter accumulation was with the crop sown during II FN of June (S_1) than with I FN of July. The latter inturn differed significantly than with that of II FN of July (S_3) sown crop. The lowest dry matter production was recorded with I FN of August (S_4) sown crop.

The highest dry matter production was with the highest nitrogen level of 60 kg N ha^{-1} (N_4) which was significantly higher than that due to 40 kg N ha^{-1} (N_3). The lower dry matter production was with control (N_1) which was significantly lower than with 20 kg N ha^{-1} (N_2).

4.2.3.3 Dry matter production at 60 DAS

Dry matter production of proso millet was higher with II FN of June (S_1) sowing, followed by that with I FN of July (S_2), II FN of July (S_3) and I FN of August (S_4) in the order of descent with significant disparity between any two of the four sowing times tried.

Higher dry matter accumulation was with application of 60 kg N ha^{-1} (N_4) which was significantly higher than with 40 kg N ha^{-1} (N_3), 20 kg N ha^{-1} (N_2) and control (N_1). Difference between any two of the lower doses of nitrogen was also significant.

4.2.3.4 Dry matter production at harvest

The highest dry matter accumulation was with the crop sown during II FN of June (S_1) followed by that due to I FN of July (S_2) and II FN of July (S_3) sowing. Each delay in sowing significantly decreased the dry matter production. The lowest dry matter production was with the crop sown during I FN of August (S_4).

Application of 60 kg N ha^{-1} (N_4) resulted in higher dry matter production followed by that with 40 kg N ha^{-1} (N_3), 20 kg N ha^{-1} (N_2) and control (N_1) which differed significantly in the order of descent.

Growth parameters like plant height, leaf area and number of tillers m^{-2} are the major elements influencing dry matter accumulation. The higher dry matter accumulation of proso millet with early sown crop might be due to longer vegetative phase along with favourable weather conditions which were ideal for enhanced growth. Similar findings were observed with Deshmukh *et al*. (2013) and Nandini and Sridhara (2019).

Dry matter production was higher with application of 60 kg N ha^{-1} (N_4) at all the stages of observation due to improvement in growth parameters like plant height, leaf area and number of tillers m^{-2}. Enhanced dry matter accumulation at higher level of nitrogen was evidenced with the reports of Jyothi *et al*. (2016) and Charate *et al*. (2018).

4.2.4 Number of Tillers m^{-2}

Times of sowing and levels of nitrogen exerted significant influence on number of tillers m^{-2} (Table 4.4 and Fig. 4.4) in proso millet at all the growth stages of crop, while their interaction was found to be non significant.

4.2.4.1 Number of tillers m^{-2} at 20 DAS

Number of tillers m^{-2} was higher with the crop sown during II FN of June (S_1) which was however on par with that of I FN of July (S_2) sowing. Crop sown during II FN of July (S_3) resulted in significantly lesser number of tillers m^{-2} than with I FN of July (S_2) sown crop, but was significantly superior to that of I FN of August (S_4).

Significantly higher number of tillers m^{-2} was recorded when proso millet was supplied with 60 kg N ha^{-1} (N_4) followed by that with 40 kg N ha^{-1} (N_3) and 20 kg N ha^{-1} (N_2). Significantly lower number of tillers m^{-2} was recorded with control (N_1) than with 20 kg N ha^{-1} (N_2).

4.2.4.2 Number of tillers m^{-2} at 40 DAS

Significantly higher number of tillers m^{-2} was with the crop sown during II FN of June (S_1). The next best sowing time in producing higher number of tillers

Table 4.4. Number of tillers m^{-2} of proso millet at different growth stages as influenced by times of sowing and nitrogen levels

Treatments	Number of tillers m^{-2}			
	20 DAS	**40 DAS**	**60 DAS**	**At harvest**
Times of Sowing (S)				
S_1 - II FN of June	154	203	236	248
S_2 - I FN of July	150	187	216	226
S_3 - II FN of July	124	164	201	210
S_4 - I FN of August	101	141	159	159
SEm±	3.8	3.9	4.0	3.6
CD (P=0.05)	13	14	14	13
Nitrogen levels (N)				
N_1 – Control	114	146	174	183
N_2 - 20 kg ha^{-1}	126	162	192	199
N_3 - 40 kg ha^{-1}	138	181	213	218
N_4 - 60 kg ha^{-1}	151	205	234	243
SEm±	3.6	3.4	3.6	3.7
CD (P=0.05)	11	10	11	11
Times of sowing (S) x Nitrogen levels (N)				
N at S				
SEm±	7.6	7.8	8.0	7.2
CD (P=0.05)	NS	NS	NS	NS
S at N				
SEm±	7.3	7.1	7.4	7.4
CD (P=0.05)	NS	NS	NS	NS

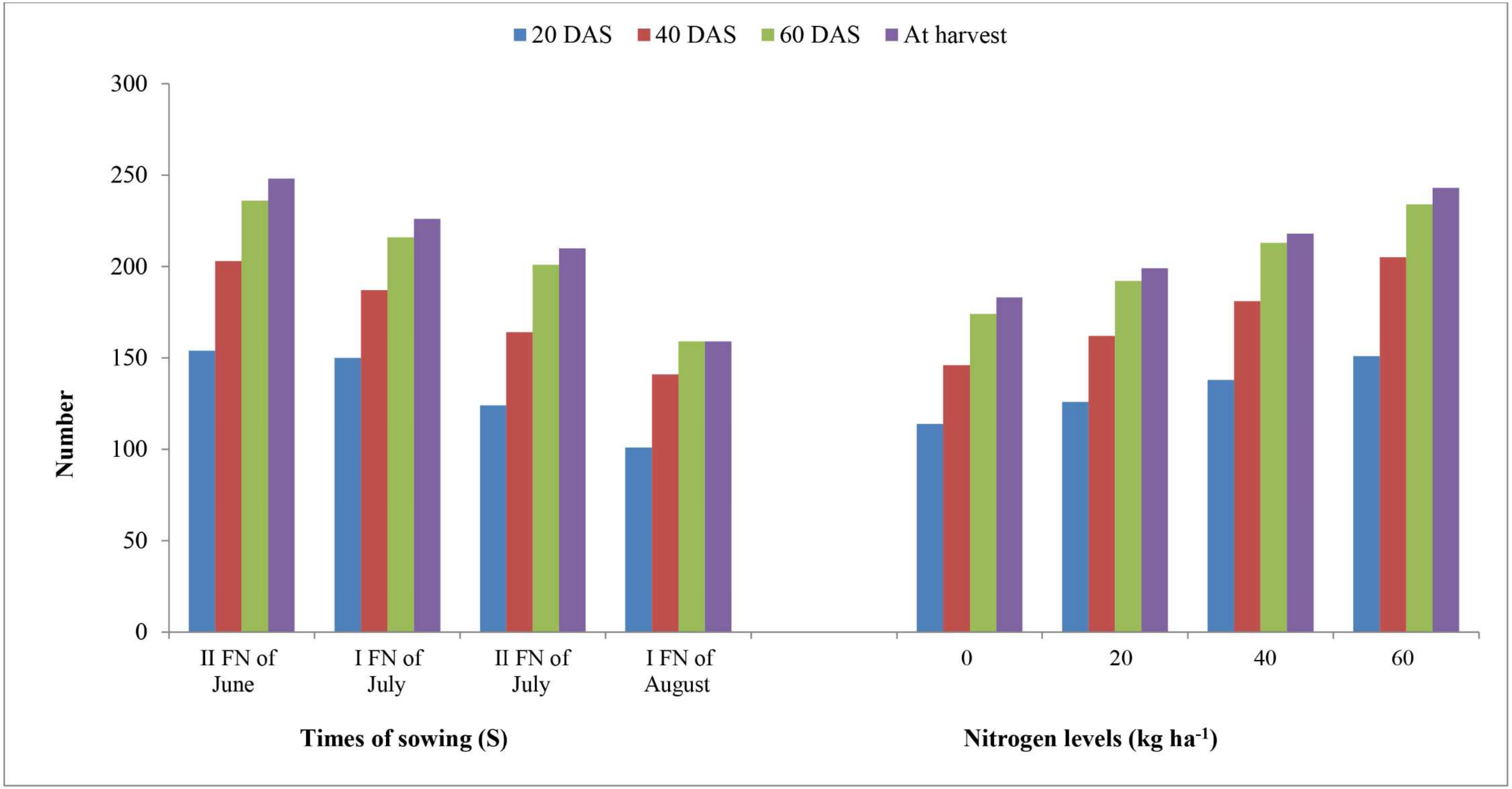

Fig. 4.4. Number of tillers m^{-2} of proso millet at different growth stages as influenced by times of sowing and nitrogen levels.

m^{-2} was I FN of July (S_2) followed by that with II FN of July (S_3) and I FN of August (S_4) with significant difference between any two of them.

Number of tillers m^{-2} of proso millet was significantly higher with application of highest level of nitrogen *i.e*. 60 kg N ha^{-1} (N_4) than with 40 kg N ha^{-1} (N_3) and 20 kg N ha^{-1} (N_2). The latter two levels of nitrogen also maintained significant disparity between them. The lowest number of tillers m^{-2} was with control (N_1).

4.2.4.3 Number of tillers m^{-2} at 60 DAS

Among the times of sowing tried, proso millet sown during II FN of June (S_1) resulted in more number of tillers m^{-2} which was significantly higher than with I FN of July (S_2). Significantly lesser number of tillers m^{-2} was noticed with I FN of August (S_4) sown crop than with II FN of July (S_3), the latter inturn differed significantly with that of I FN of July (S_2) sown crop.

Application of 60 kg N ha^{-1} (N_4) to proso millet produced higher number of tillers m^{-2} than with 40 kg N ha^{-1} (N_3) and 20 kg N ha^{-1} (N_2) with significant disparity between any two of the three nitrogen levels. Significantly lesser number of tillers m^{-2} were with control (N_1).

4.2.4.4 Number of tillers m^{-2} at harvest

Number of tillers m^{-2} of proso millet with II FN of June (S_1) sowing was significantly higher than with I FN of July (S_2), the latter was inturn significantly superior to that of II FN of July (S_3). Crop sown during I FN of August (S_4) had significantly lesser number of tillers m^{-2}.

Proso millet supplied with 60 kg N ha^{-1} (N_4) resulted in higher number of tillers m^{-2} followed by that with 40 kg N ha^{-1} (N_3), 20 kg N ha^{-1} (N_2) and control (N_1) in the order of descent with significant disparity between any two of the four nitrogen levels tested.

Proso millet sown during II FN of June (S_1) resulted in maximum number of tillers m^{-2}. This might be due to the fact that early sown crop had experienced longer period of vegetative growth coupled with favourable weather conditions. Higher moisture availablility during the crop growth period might have led to production of more number of tiller buds which resulted in higher number of tillers m^{-2}. Significant reduction in number of tillers m^{-2} with delay in sowing might be due to delay in germination coupled with lower atmospheric temperatures. The obtained results were similar with the findings of Mubeena *et al*. (2019).

The increase in number of tillers m^{-2} with each successive level of nitrogen might be owing to its role in cytokinin synthesis, which promoted the growth and development of tiller buds at each node of the shoot. Thus, the development of tiller primordium is dependent on the nitrogen supplied to it and was positively correlated with nitrogen dose received by the crop. The results were closely related with the findings of Singh and Maurya (2013) and Arshewar *et al*. (2018).

4.2.5 Days to 50 Per cent Flowering

Variation in sowing time and nitrogen levels exerted significant influence on days to 50 per cent flowering (Table 4.5) while their interaction was not apparent.

Number of days to 50 per cent flowering was significantly higher with the crop sown during II FN of June (S_1) relative to that with I FN of July (S_2), II FN of July (S_3) and I FN of August (S_4). Difference in duration to 50 per cent flowering due to second, third and fourth sowing was also significant. Reduction in the number of days to 50 per cent flowering with delay in sowing might be due to the fact that in short day plants flowering is induced earlier with relative reduction in day length (Reddy and Reddy, 2008).The results were similar with the findings of Ashoka and Halikatti (1997).

Days to 50 per cent flowering was earlier with 60 kg N ha^{-1} (N_4) followed by that due to 40 kg N ha^{-1} (N_3) both of which differed significantly. The latter was however on par with that of 20 kg N ha^{-1} (N_2). Significantly more number of days to 50 per cent was with control (N_1). Earlier flowering at higher nitrogen levels

Table 4.5. Days to 50 per cent flowering and days to maturity of proso millet as influenced by times of sowing and nitrogen levels

Treatments	Days to 50 per cent flowering	Days to maturity
Times of Sowing (S)		
S_1 - II FN of June	45	76
S_2 - I FN of July	42	74
S_3 - II FN of July	40	71
S_4 - I FN of August	37	69
SEm±	0.3	0.3
CD (P=0.05)	1	1
Nitrogen levels (N)		
N_1 - Control	44	75
N_2 - 20 kg ha^{-1}	41	73
N_3 - 40 kg ha^{-1}	41	72
N_4 - 60 kg ha^{-1}	39	70
SEm±	0.3	0.4
CD (P=0.05)	1	1
Times of sowing (S) x Nitrogen levels (N)		
N at S		
SEm±	0.6	0.6
CD (P=0.05)	NS	NS
S at N		
SEm±	0.6	0.7
CD (P=0.05)	NS	NS

might be due to the role of poly amines (low molecular weight organic compounds) in cell division, embryogenesis, floral initiation and development within the scheduled period of crop ontogeny (Evans and Malmberg, 1989). These results are in confirmity with the findings of Kiranmai (2015).

4.2.6 Days to Maturity

Days to maturity of proso millet differed significantly due to times of sowing and levels of nitrogen, while their interaction was not statistically traceable (Table 4.5).

Longer duration to maturity of proso millet was with the crop sown during II FN of June (S_1) followed by that with I FN of July (S_2), II FN of July (S_3) and I FN of August (S_4) with significant disparity between any two of the four times of sowing tested in the order of descent. Earlier sown crop took more time to achieve maturity, which progressively decreased with delay in sowing. Reddy *et al.* (1991) reported that with delay in sowing, flowering was induced earlier, resulting in less vegetative growth and earliness in maturity. The results obtained in the present investigation were similar with the findings of Ashoka and Halikatti (1997).

Application of 60 kg N ha^{-1} (N_4) significantly hastened maturity of proso millet compared to that of 40 kg N ha^{-1} (N_3). The latter was however on par with that of 20 kg N ha^{-1} (N_2). Crop with no nitrogen (N_1) application took significantly more number of days to maturity. Surplus availability of nitrogen with 60 kg N ha^{-1} (N_4) might have helped the crop to complete it's vegetative phase within stipulated time and allowed to reach 50 per cent flowering earlier which inturn might have reduced the number of days to maturity. These results are in confirmity with the findings of Kiranmai (2015).

4.3 YIELD ATTRIBUTES

4.3.1 Number of Panicles m^{-2}

Number of panicles m^{-2} (Table 4.6 and Fig. 4.6) varied conspicuously due to times of sowing and levels of nitrogen while their interaction effect was found to be non significant.

Higher number of panicles m^{-2} was with II FN of June (S_1) sown crop, but was however comparable with that of I FN of July (S_2), the later was inturn significantly superior to that of II FN of July (S_3) sown crop. Significantly lesser number of panicles m^{-2} was with I FN of August (S_4) sown crop. The highest number of panicles m^{-2} with early sown crop might be due to the fact that early sown proso millet enjoyed congenial climatic conditions along with required biotic and abiotic resources, which enabled the plant to produce higher number of tillers m^{-2} and hence the higher number of panicles m^{-2} (Miller *et al*., 1991). Similar results were obtained by Himasree (2016).

Among the nitrogen doses, application of 60 kg N ha^{-1} (N_4) resulted in significantly more number of panicles m^{-2}than with 40 kg N ha^{-1} (N_3). Difference between 40 kg N ha^{-1} (N_3) and 20 kg N ha^{-1} (N_2) in producing number of panicles m^{-2} was also significant. The least number of panicles m^{-2} was with control (N_1). Application of highest nitrogen level of 60 kg N ha^{-1} (N_4) resulted in maximum number of panicles m^{-2}, presumely due to cumulative improvement in various growth parameters like dry matter accumulation, leaf area and number of tillers m^{-2}. Similar findings were observed by Yadav *et al*. (2010), Singh and Maurya (2013) and Arshewar *et al*. (2018).

4.3.2 Length of the Panicle

Length of the panicle (Table 4.6 and Fig. 4.6) in proso millet differed significantly due to times of sowing and levels of nitrogen but not by their interaction.

Table 4.6. Number of panicles m^{-2} and length of the panicle of proso millet as influenced by times of sowing and nitrogen levels

Treatments	Number of panicles m^{-2}	Length of the panicle (cm)
Times of Sowing (S)		
S_1 - II FN of June	113	25.7
S_2 - I FN of July	105	24.8
S_3 - II FN of July	95	23.2
S_4 - I FN of August	78	20.4
SEm±	2.4	0.31
CD (P=0.05)	8	1.1
Nitrogen levels (N)		
N_1 - Control	81	20.4
N_2 - 20 kg ha^{-1}	93	22.8
N_3 - 40 kg ha^{-1}	103	24.5
N_4 - 60 kg ha^{-1}	114	26.5
SEm±	2.7	0.25
CD (P=0.05)	8	0.7
Times of sowing (S) × Nitrogen levels (N)		
N at S		
SEm±	4.7	0.63
CD (P=0.05)	NS	NS
S at N		
SEm±	5.3	0.53
CD (P=0.05)	NS	NS

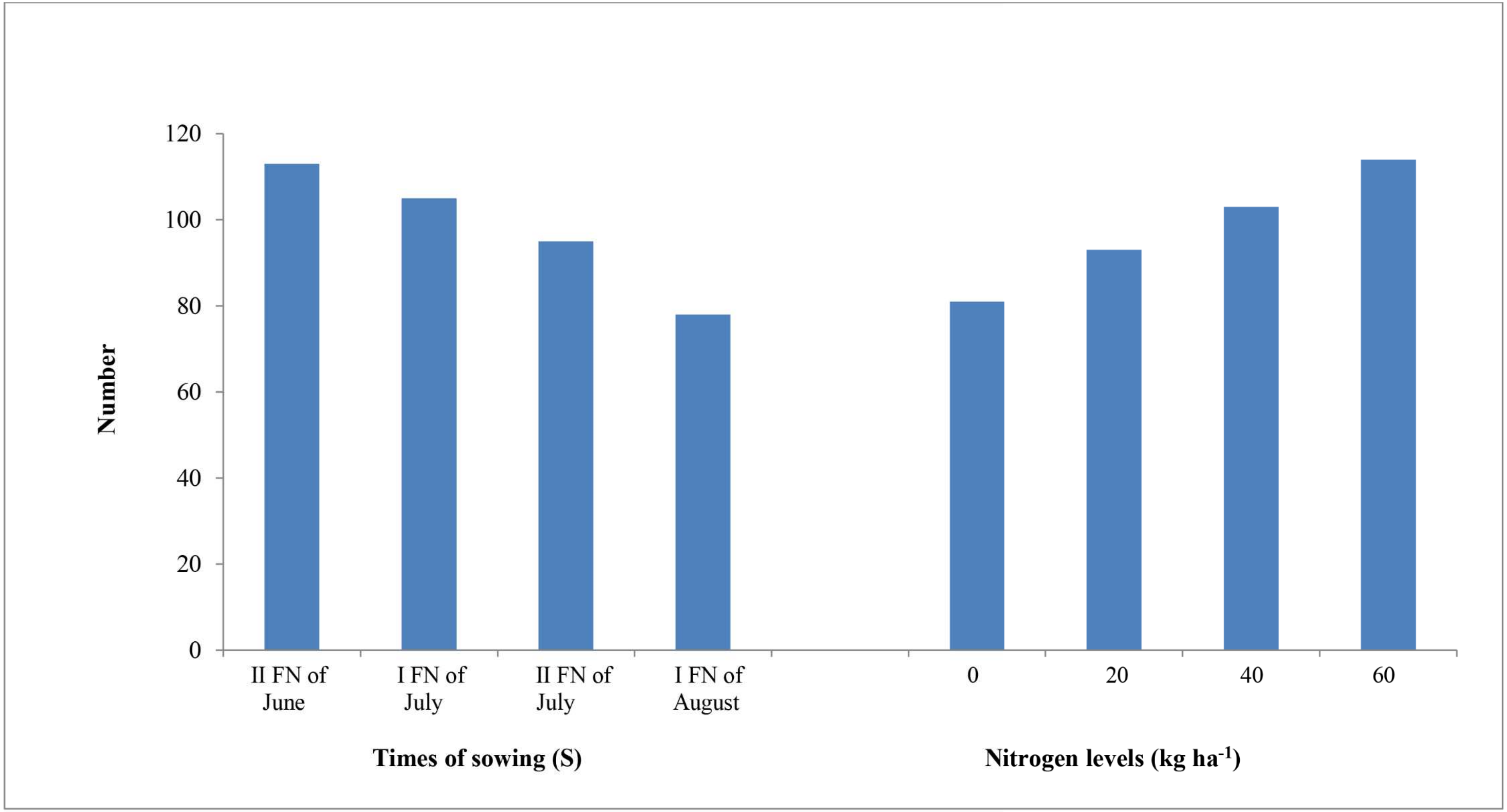

Fig. 4.5. Number of panicles m^{-2} of proso millet as influenced by times of sowing and nitrogen levels.

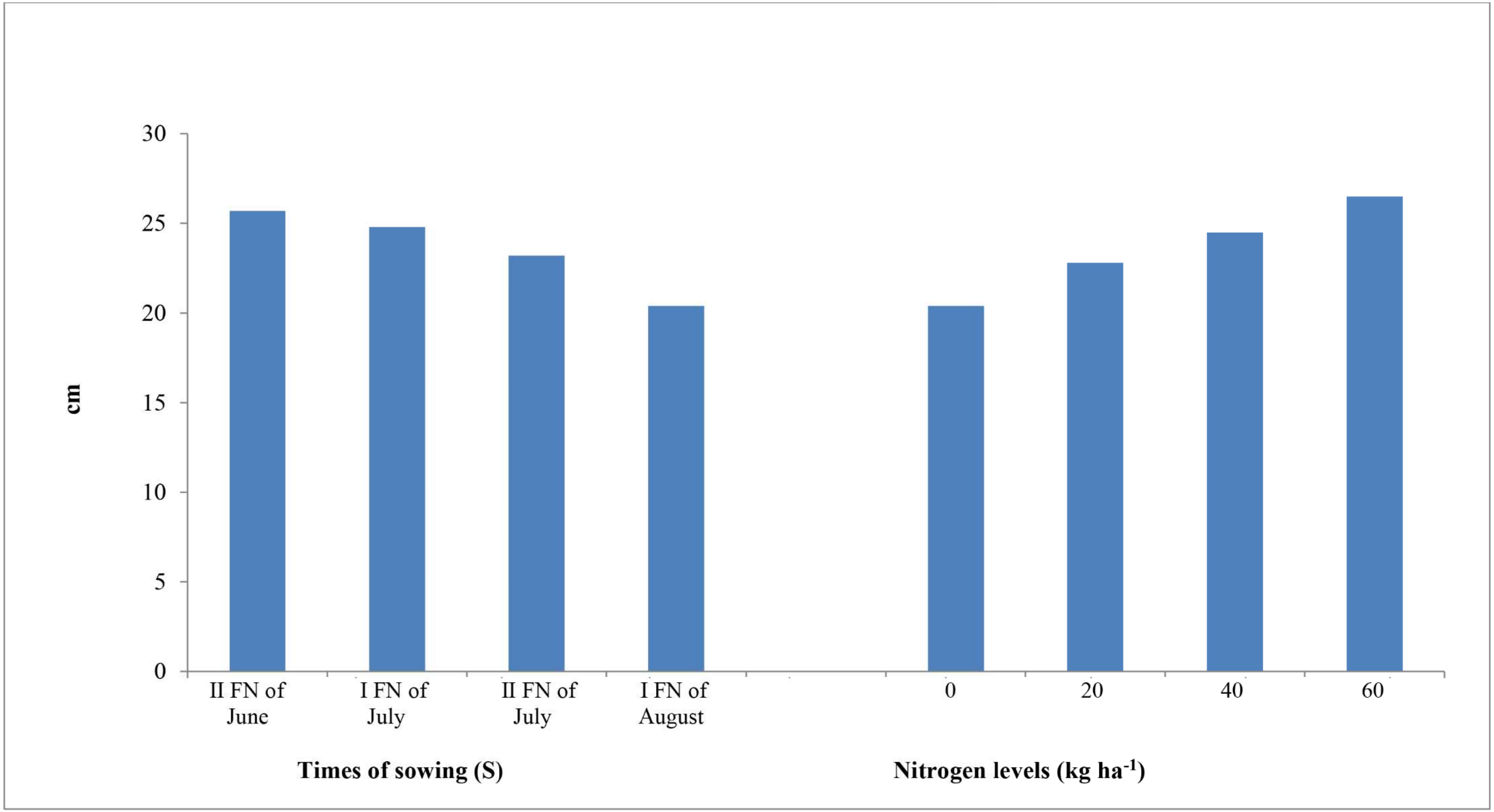

Fig. 4.6. Length of the panicle (cm) of proso millet as influenced by times of sowing and nitrogen levels.

The lengthier panicles were with the early sown crop during II FN of June (S_1) which was however on par with that of I FN of July (S_2). The latter was significantly superior to that of II FN of July (S_3) sown crop. Significantly shorter panicles were noticed with I FN of August (S_4) sown crop. Lengthier panicles with early sown crop might be owing to higher dry matter accumulation in the panicle and better translocation of assimilates from source to the sink. Above results corrobates with the findings of Nandini and Sridhara (2019).

The highest nitrogen level of 60 kg N ha^{-1} (N_4) resulted in higher panicle length followed by that with 40 kg N ha^{-1} (N_3) and 20 kg N ha^{-1} (N_2). Difference in length of panicle due to latter two nitrogen levels was also found to be significant. The lowest panicle length was with control (N_1). Maximum panicle length with higher dose of nitrogen might be attributed to the fact that higher availability of nitrogen have equipped the plant with luxuriant availability of photosynthates which inturn favoured the better partitioning of assimilates from source to sink. Linear increase in panicle length with increased doses of nitrogen as evident in this investigation was found to be similar with the findings of Pradhan *et al*. (2015) and Charate *et al*. (2018).

4.3.3 Weight of Grains Panicle^{-1}

Weight of grains panicle^{-1} (Table 4.7 and Fig. 4.7) of proso millet was significantly influenced by times of sowing and levels of nitrogen. While their interaction was found to be non significant.

The higher grain weight panicle^{-1} was registered with crop sown during II FN of June (S_1) followed by that with I FN of July (S_2) and II FN of July (S_3) sown crop with significant disparity between any two of them. The lowest grain weight panicle^{-1} was with I FN of August (S_4) sown crop. The higher grain weight panicle^{-1} with early sown crop (II FN of June) might be due to increased panicle length and sink capacity because of which the efficient translocation of assimilates from source to the sink occurred. These results are in confirmity with the results of Nandini and Sridhara (2019).

Table 4.7. Weight of grains panicle^{-1} and 1000 grain weight of proso millet as influenced by times of sowing and nitrogen levels

Treatments	Weight of grains panicle^{-1} (g)	1000 grain weight (g)
Times of Sowing (S)		
S_1 - II FN of June	5.66	6.07
S_2 - I FN of July	5.48	5.90
S_3 - II FN of July	5.26	5.60
S_4 - I FN of August	4.54	5.32
SEm±	0.041	0.045
CD (P=0.05)	0.14	0.16
Nitrogen levels (N)		
N_1 - Control	4.42	5.28
N_2 - 20 kg N ha^{-1}	4.79	5.56
N_3 - 40 kg N ha^{-1}	5.45	5.89
N_4 - 60 kg N ha^{-1}	6.29	6.14
SEm±	0.067	0.089
CD (P=0.05)	0.20	0.23
Times of sowing (S) × Nitrogen levels (N)		
N at S		
SEm±	0.081	0.089
CD (P=0.05)	NS	NS
S at N		
SEm±	0.123	0.144
CD (P=0.05)	NS	NS

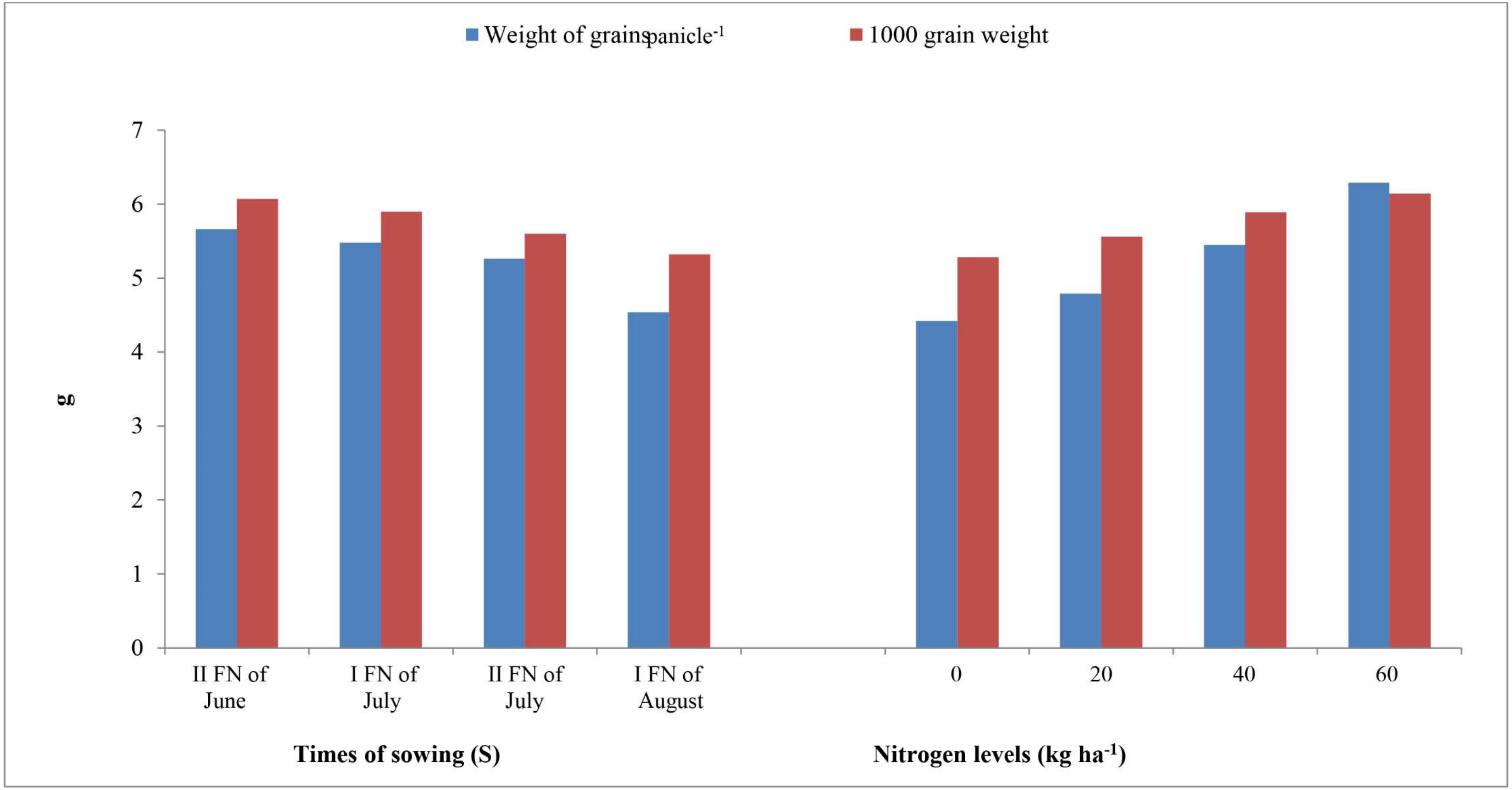

Fig. 4.7. Weight of grains panicle^{-1} and 1000 grain weight (g) of proso millet as influenced by times of sowing and nitrogen levels.

Significantly higher weight of grains panicle^{-1} was observed with application of 60 kg N ha^{-1} (N_4) than with other lower nitrogen levels. The next best nitrogen dose was 40 kg N ha^{-1} (N_3) which was significantly superior to that of 20 kg N ha^{-1} (N_2). The lowest weight of grains panicle^{-1} was with control (N_1). Increase in weight of grains panicle^{-1} with increased nitrogen levels might be due to better growth of the crop, efficient dry matter partitioning and better translocation of assimilates to the sink leading to formation of more number of filled grains and large sized grains. The results obtained corroborates with the findings of Yadav and Yadav (2013).

4.3.4 1000 Grain Weight

Thousand grain weight (Table 4.7 and Fig. 4.7) varied conspicuously due to times of sowing and levels of nitrogen whereas their interaction was not statistically traceable.

Thousand grain weight of proso millet was significantly higher with the crop sown during II FN of June (S_1) than with I FN of July (S_2). Delay in sowing from I FN of July (S_2) to II FN of July (S_3) significantly reduced the thousand grain weight. Significantly lesser thousand grain weight was with the crop sown during I FN of August (S_4). Reduction in thousand grain weight of proso millet with delay in sowing from II FN of June (S_1) to I FN of August (S_4) was due to reduction in grain filling period. The results are in agreement with the findings of Nandini and Sridhara (2019).

Application of 60 kg N ha^{-1} (N_4) resulted in significantly higher thousand grain weight compared with lower levels of nitrogen tested. Differences between all the nitrogen doses tested were also significant with no nitrogen (N_1) application recording the least thousand grain weight. Higher nitrogen level of 60 kg N ha^{-1} might have improved the source-sink relationship with better translocation of photosynthates for grain filling and development and hence resulted in increased thousand grain weight. These results are in accordance with the findings of Jyothi *et al*. (2016).

4.4 YIELD

4.4.1 Grain Yield

Times of sowing as well as nitrogen levels significantly influenced the grain yield (Table 4.8 and Fig. 4.8) of proso millet, however their interaction was not statistically measurable.

The highest grain yield was realized when proso millet was sown during II FN of June (S_1) followed by that with I FN of July (S_2) and II FN of July (S_3) with significant disparity between any two of them. Significantly lower grain yield was obtained with the crop sown during I FN of August (S_4). Early sown crop might have experienced favourable weather conditions with prolonged photoperiod due to which higher assimilates were translocated towards panicle and hence resulted in higher panicle length, grain weight panicle^{-1}, test weight and thus the grain yield. The results of present investigation are in agreement with the findings of Maurya *et al.* (2016) and Mubeena *et al.* (2019).

Application of 60 kg N ha^{-1} (N_4) resulted in significantly higher grain yield relative to that of lower levels of nitrogen. The next best nitrogen level in realizing higher grain yield was 40 kg N ha^{-1} (N_3) which was significantly superior to that of 20 kg N ha^{-1} (N_2). Significantly lesser grain yield of proso millet was with control (N_1). Crop growth and productivity depends on the ability of the plant to absorb, metabolize and utilise the nitrogen assimilates to its genetic potential. Nitrogen metabolism results in production of carbon assimilates and their utilization for reproductive growth. Therefore better availability of nitrogen with 60 kg ha^{-1} (N_4) might have enhanced the total biomass accumulation and its efficient translocation from source to sink which resulted in elevated growth (dry matter production, leaf area and number of tillers m^{-2}) and yield parameters (panicle length, grain weight panicle^{-1} and test weight) and hence the grain yield. The linear increase in grain yield with increased supply of nitrogen was reported by several workers *viz.,* Jyothi *et al.* (2016), Arshewar *et al.* (2018) and Mubeena *et al.* (2019).

Table 4.8. Grain and straw yield of proso millet as influenced by times of sowing and nitrogen levels

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Times of Sowing (S)		
S_1 - II FN of June	1239	2909
S_2 - I FN of July	1145	2688
S_3 - II FN of July	1052	2428
S_4 - I FN of August	745	2131
SEm±	25.4	52.6
CD (P=0.05)	90	185
Nitrogen levels (N)		
N_1 – Control	796	2058
N_2 - 20 kg ha^{-1}	954	2448
N_3 - 40 kg ha^{-1}	1127	2672
N_4 - 60 kg ha^{-1}	1304	2977
SEm±	36.3	71.9
CD (P=0.05)	107	211
Times of sowing (S) × Nitrogen levels (N)		
N at S		
SEm±	50.9	105.2
CD (P=0.05)	NS	NS
S at N		
SEm±	67.9	135.3
CD (P=0.05)	NS	NS

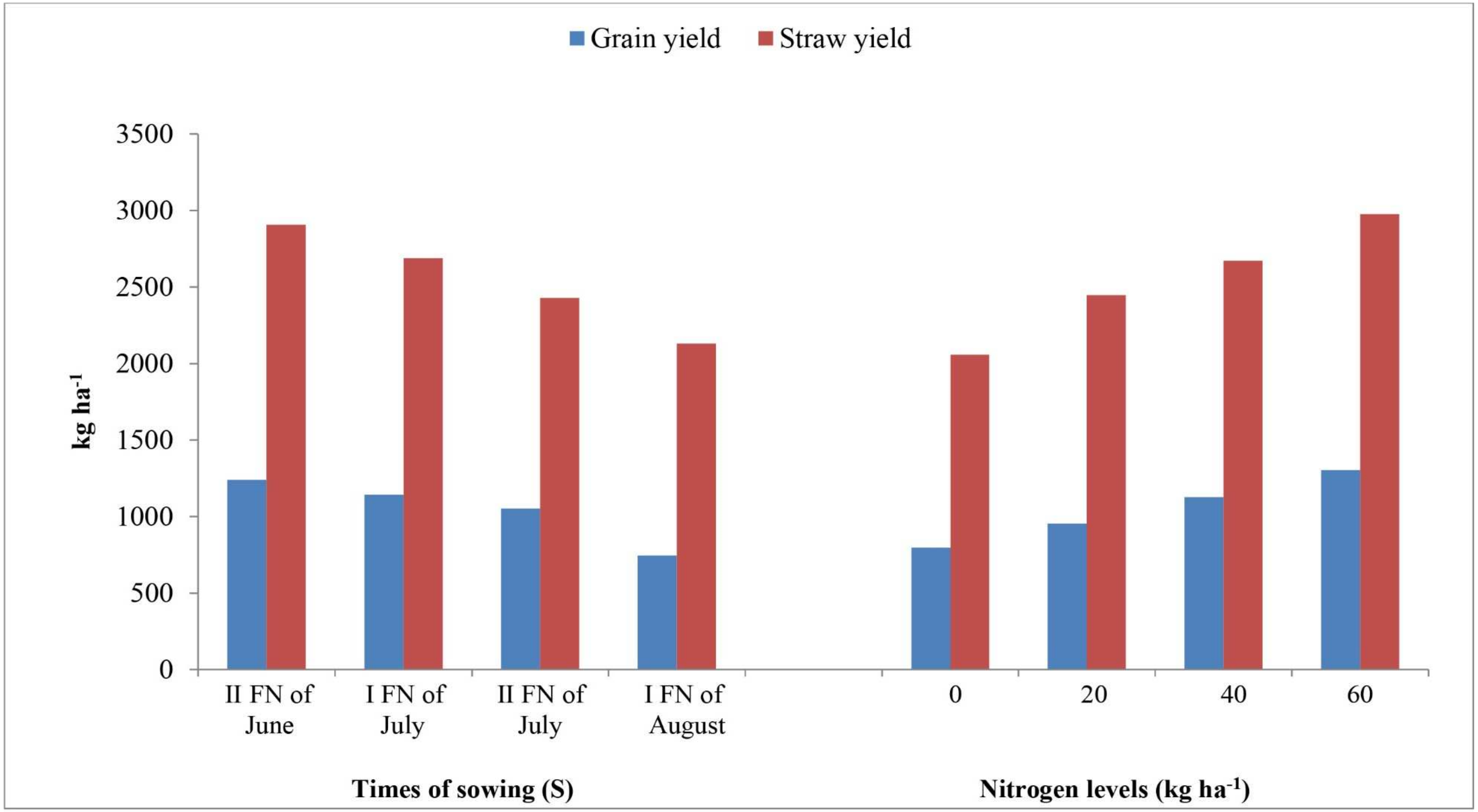

Fig. 4.8. Grain and straw yield (kg ha^{-1}) of proso millet as influenced by times of sowing and nitrogen levels.

4.4.2 Straw Yield

Times of sowing and nitrogen levels exerted significant effect on the straw yield (Table 4.8 and Fig. 4.8) of proso millet, while their interaction effect was found to be non significant.

Significantly higher straw yield was with proso millet sown during II FN of June (S_1) than that with I FN of July (S_2). Crop sown during I FN of July (S_2) resulted insignificantly higher straw yield than with II FN of July (S_3). Significantly lesser straw yield was with the crop sown during I FN of August (S_4). Higher straw yield with II FN of June sown crop might be due to favourable weather conditions like bright sunshine hours and adequate rainfall that has resulted in better growth parameters like plant height, leaf area and dry matter accumulation which have directly influenced straw yield. These results were similar with the findings of Mubeena *et al*. (2019) and Nandini and Sridhara (2019).

Application of 60 kg N ha^{-1} (N_4) resulted in higher straw yield than with 40 (N_3) and 20 kg N ha^{-1} (N_2) with significant disparity between any two of them. Significantly lower straw yield was realized with control (N_1). Adequate supply of nitrogen through 60 kg N ha^{-1} (N_4) resulted in higher vegetative growth with taller plants, good dry matter accumulation and more leaf area which in turn fetched higher straw yield. The increased straw yield with increase in nitrogen level as resulted from the present investigation corroborates with the findings of Munirathnam and Kumar (2015) and Pradhan *et al*. (2015).

4.5 POST HARVEST SOIL NUTRIENT STATUS

Times of sowing and levels of nitrogen (Table 4.9 and Fig. 4.9) exerted significant influence on post harvest soil nutrient status (available nitrogen, phosphorus and potassium). The interaction between times of sowing and nitrogen levels was found to be non significant.

Significantly higher values of post harvest soil available nitrogen, phosphorus and potassium were with I FN of August (S_4) sown crop. This was

Table 4.9. Post harvest soil available N, P_2O_5 and K_2O as influenced by times of sowing and nitrogen levels in proso millet

Treatments	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
Times of Sowing (S)			
S_1 - II FN of June	157.0	27.9	120.0
S_2 - I FN of July	170.0	29.3	131.0
S_3 - II FN of July	183.0	31.3	144.0
S_4 - I FN of August	194.0	32.5	157.0
SEm±	2.89	0.29	3.03
CD (P=0.05)	10.0	1.0	10.0
Nitrogen levels (N)			
N_1 – Control	154.0	32.1	159.0
N_2 - 20 kg ha^{-1}	170.0	30.8	143.0
N_3 - 40 kg ha^{-1}	184.0	29.5	131.0
N_4 - 60 kg ha^{-1}	196.0	28.3	119.0
SEm±	3.77	0.39	3.50
CD (P=0.05)	11.0	1.1	10.0
Times of sowing (S) x Nitrogen levels (N)			
N at S			
SEm±	5.78	0.58	6.06
CD (P=0.05)	NS	NS	NS
S at N			
SEm±	7.14	0.74	6.77
CD (P=0.05)	NS	NS	NS

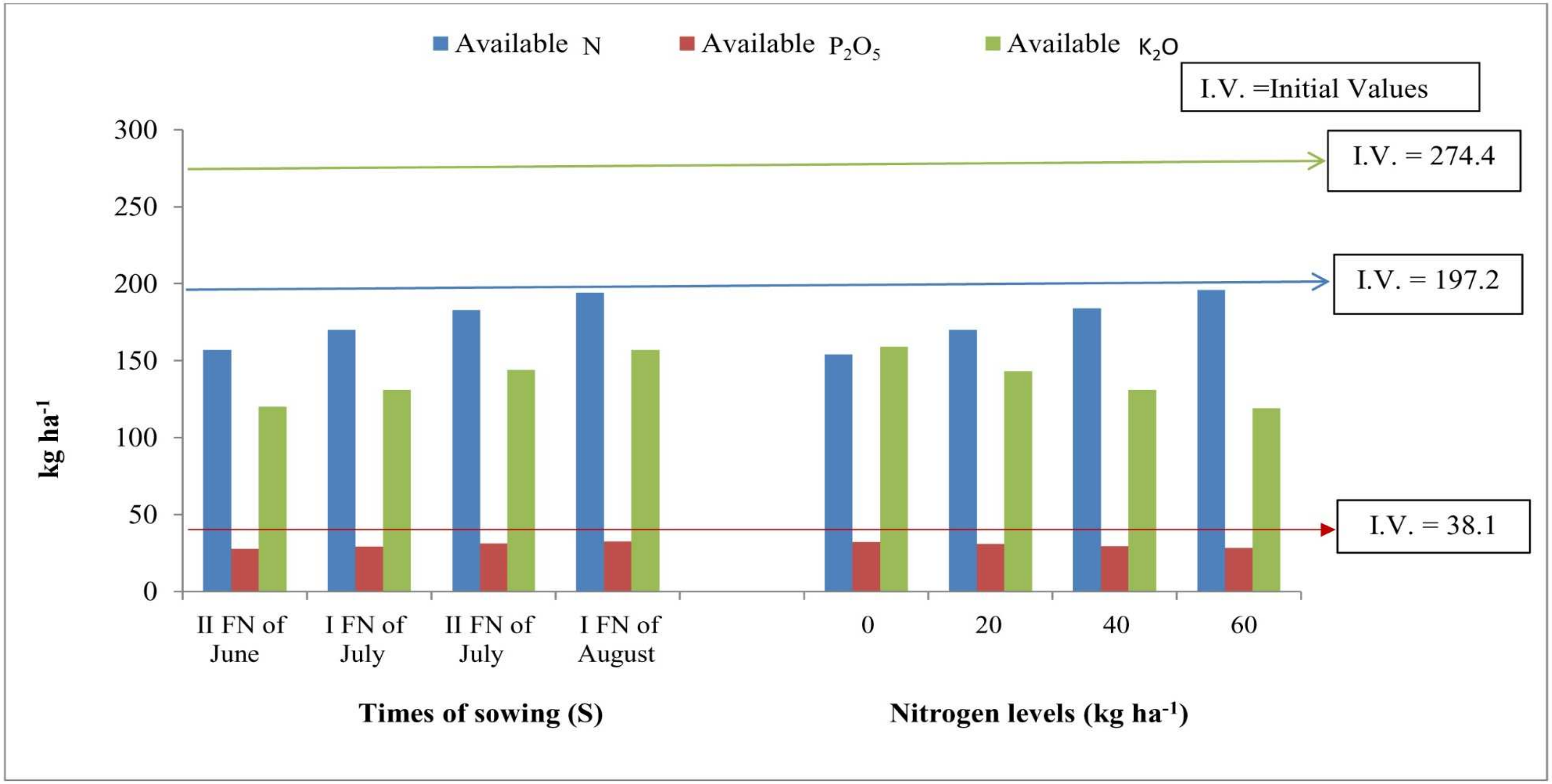

Fig. 4.9. Post harvest soil available N, P_2O_5 and K_2O (kg ha^{-1}) as influenced by times of sowing and nitrogen levels in proso millet.

followed by that with II FN of July (S_3), I FN of July (S_2) and II FN of June (S_1) with significant disparity between any two of the three times of sowing. Reduction in soil available nutrients with early sown crop might be due to higher nutrient uptake efficiency of the crop. Increase in post harvest soil available nutrients with delayed sowing as resulted from the present experiment is similar with the findings of Gavit *et al.* (2017).

Post harvest soil available nitrogen increased significantly with successive increment in nitrogen level from 0 to 60 kg ha^{-1}. Higher post harvest soil available nitrogen with 60 kg N ha^{-1} (N_4) was due to higher microbial activity which mineralized the organic nitrogen coupled with nitrogen added to the soil through urea. Higher soil available phosphorus and potassium were with control (N_1) which was significantly higher than with that of 20 kg (N_2) and 40 kg N ha^{-1} (N_3). Significantly lower soil available phosphorus and potassium was with 60 kg N ha^{-1} (N_4). Application of 60 kg N ha^{-1} (N_4) has led to better uptake of phosphorus and potassium from the soil, resulting in their lower availability in the soil at harvest. These results corroborates with the findings of Kiranmai (2015).

4.6 NUTRIENT UPTAKE

Nutrient uptake (N, P and K) of proso millet differed significantly due to times of sowing and nitrogen levels. Interaction could not show significant variation on nutrient uptake by the crop.

The highest uptake of nitrogen, phosphorus and potassium (Table 4.10 and Fig. 4.10) was with early sown crop during II FN of June (S_1) which was significantly higher than that with latter sowings. The next best sowing time was I FN of July (S_2) which was significantly higher than that due to II FN of July (S_3). Significantly lower nutrient uptake was with I FN of August (S_4) sown crop. Higher nutrient uptake with early sown crop was due to longer vegetative lag phase of the crop for efficient use of growth resources leading to higher dry matter accumulation. Similar results were obtained by Mubeena *et al.* (2019).

Table 4.10. Nutrient uptake at harvest by proso millet as influenced by times of sowing and nitrogen levels

Treatments	Nitrogen uptake(kg ha^{-1})	Phosphorus uptake (kg ha^{-1})	Potassium uptake (kg ha^{-1})
Times of Sowing (S)			
S_1 - II FN of June	24.4	13.4	101.0
S_2 - I FN of July	22.5	12.1	98.0
S_3 - II FN of July	21.5	10.9	92.0
S_4 - I FN of August	18.4	9.4	87.0
SEm±	0.19	0.30	0.79
CD (P=0.05)	0.7	1.0	3.0
Nitrogen levels (N)			
N_1 - Control	16.6	9.1	84.0
N_2 - 20 kg ha^{-1}	21.0	10.6	92.0
N_3 - 40 kg ha^{-1}	23.2	12.3	97.0
N_4 - 60 kg ha^{-1}	26.0	13.8	104.0
SEm±	0.59	0.45	1.26
CD (P=0.05)	1.7	1.3	4.0
Times of sowing (S) x Nitrogen levels (N)			
N at S			
SEm±	0.38	0.59	1.58
CD (P=0.05)	NS	NS	NS
S at N			
SEm±	1.04	0.83	2.32
CD (P=0.05)	NS	NS	NS

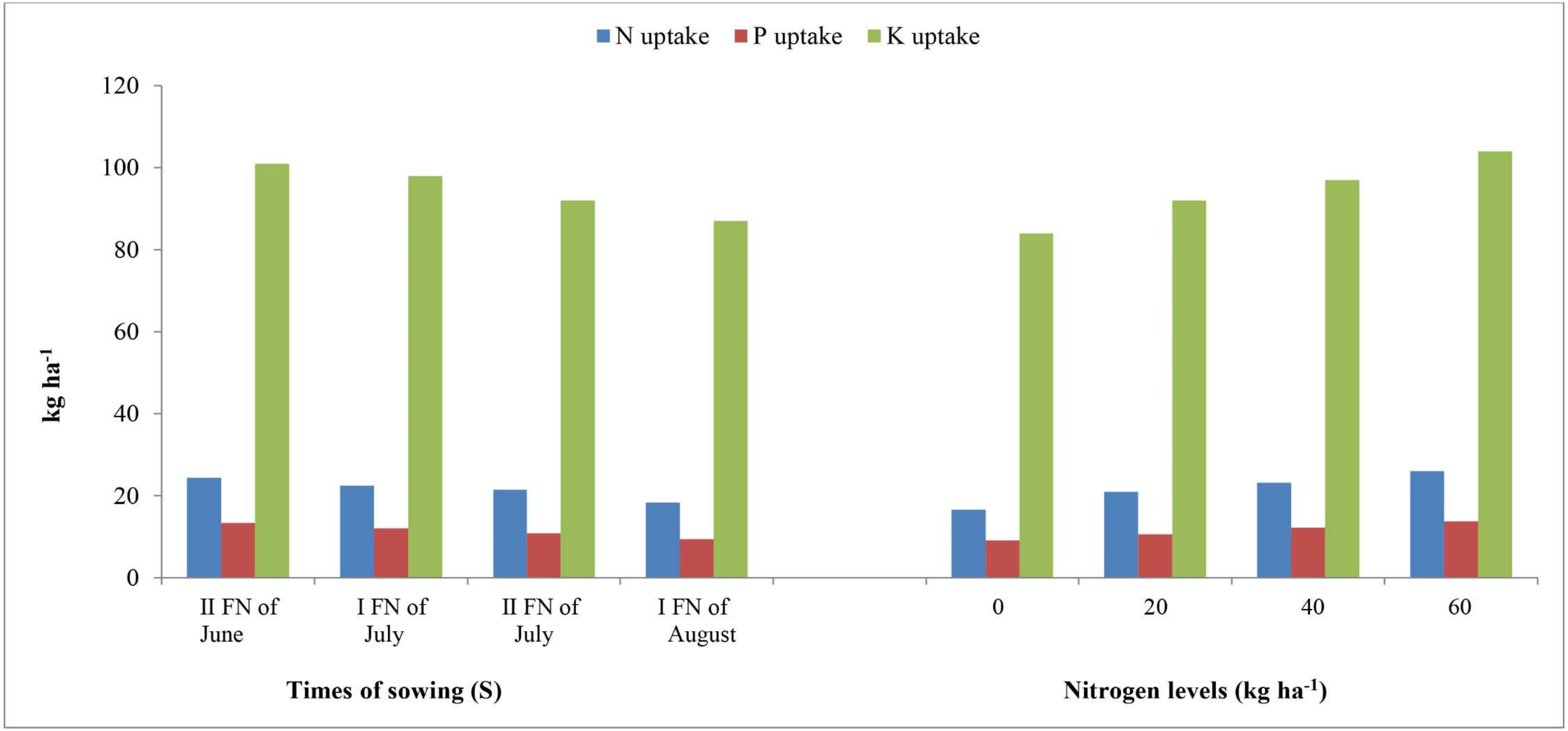

Fig. 4.10. Nutrient uptake (kg ha^{-1}) at harvest of proso millet as influenced by times of sowing and nitrogen levels.

Application of 60 kg N ha^{-1} (N_4) resulted in higher nutrient uptake followed by that with 40 kg N ha^{-1} (N_3), 20 kg N ha^{-1} (N_2) and control (N_1) in the order of descent with significant difference between any two of the nitrogen levels tested. Application of 60 kg N ha^{-1} (N_4) improved the microbial activity through enhanced root exudates and increased translocation of nutrients which might have contributed to higher nitrogen, phosphorus and potassium contents respectively in the plant tissue which were further being complemented with their higher dry matter production. These results are in accordance with the findings of Jyothi *et al*. (2016).

4.7 ECONOMICS

Gross returns, net returns and benefit:cost ratio (Table 4.11 and Fig. 4.11) of proso millet differed significantly with times of sowing and levels of nitrogen. Interaction between times of sowing and levels of nitrogen was not significant in influencing the economic returns.

4.7.1 Gross Returns

Gross returns were the highest with the crop sown during II FN of June (S_1), which was significantly higher than that due to other times of sowing. Crop sown during I FN of July (S_2) gave significantly higher gross returns than that of II FN of July (S_3). The lowest gross returns was realized with I FN of August (S_4) sown crop.

Significantly higher gross returns were due to the highest nitrogen dose of 60 kg ha^{-1} (N_4) compared with the other lower nitrogen levels. Difference in gross returns due to the lower doses were also significant. The lowest gross returns were with control (N_1).

4.7.2 Net Returns

The highest net returns were obtained with proso millet sown during II FN of June (S_1) which was significantly higher than due to I FN of July (S_2). The

Table 4.11. Economics of proso millet as influenced by times of sowing and nitrogen levels

Treatments	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	Benefit:cost ratio
Times of Sowing (S)			
S_1 - II FN of June	65069	42821	2.87
S_2 - I FN of July	60103	37855	2.65
S_3 - II FN of July	55244	32996	2.44
S_4 - I FN of August	39099	16851	1.72
SEm±	925.2	1064.6	0.054
CD (P=0.05)	3264	3755	0.19
Nitrogen levels (N)			
N_1 - Control	41787	20679	1.95
N_2 - 20 kg ha^{-1}	50109	27741	2.21
N_3 - 40 kg ha^{-1}	59158	36530	2.58
N_4 - 60 kg ha^{-1}	68460	45572	2.95
SEm±	1461.2	1033.0	0.074
CD (P=0.05)	4290	3033	0.22
Times of sowing (S) x Nitrogen levels (N)			
N at S			
SEm±	1850.4	2129.1	0.107
CD (P=0.05)	NS	NS	NS
S at N			
SEm±	2694.7	2081.9	0.139
CD (P=0.05)	NS	NS	NS

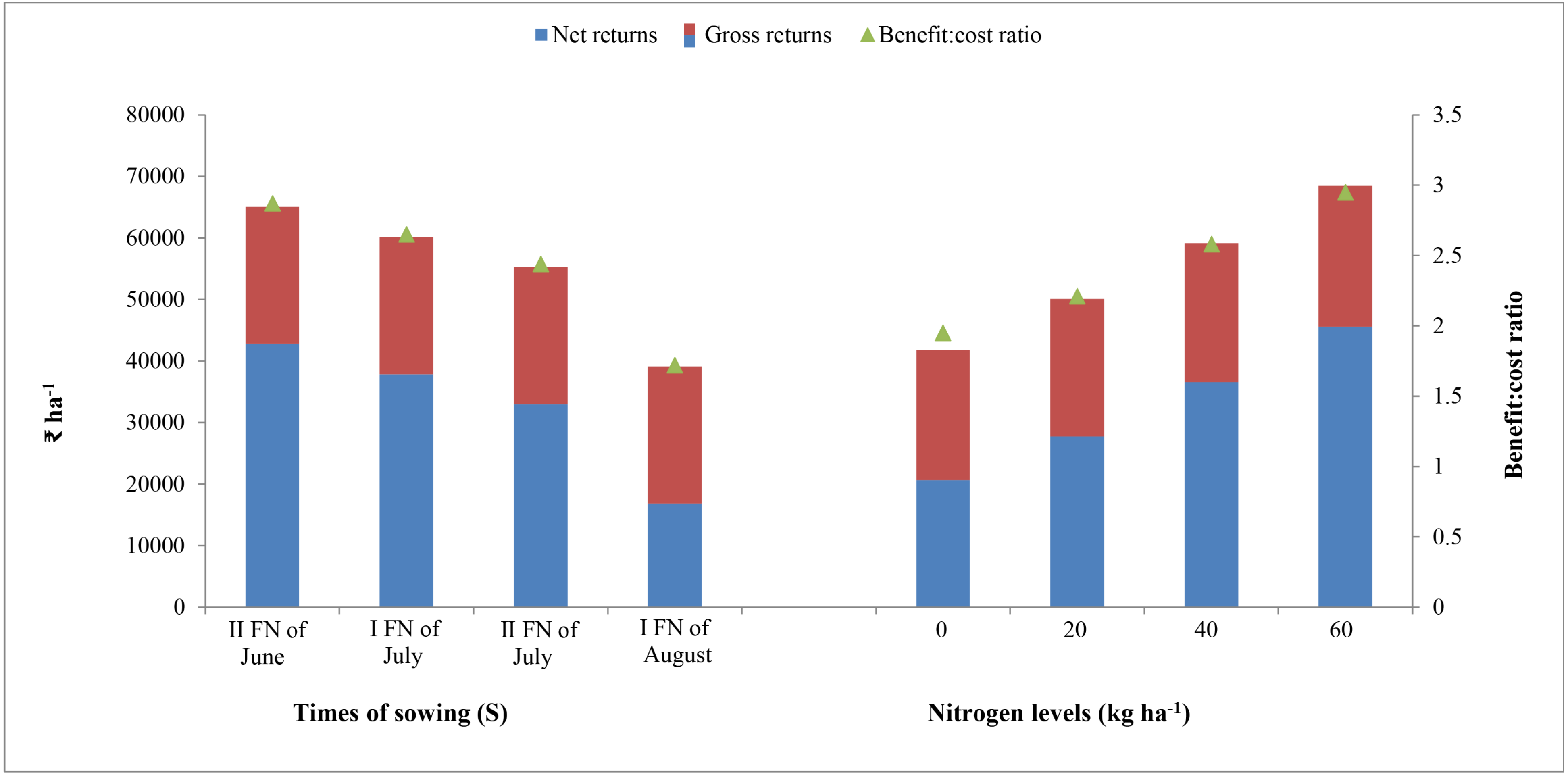

Fig. 4.11. Economics of proso millet as influenced by times of sowing and nitrogen levels.

next best sowing time in realizing higher net returns was II FN of July (S_3) which was significantly higher than that with I FN of August (S_4).

Proso millet supplied with 60 kg N ha^{-1} (N_4) resulted in higher net returns which was significantly superior over 40 kg ha^{-1} (N_3). Significantly lower net returns were with control (N_1) than that of 20 kg ha^{-1} (N_2).

4.7.3 Benefit:Cost Ratio

Benefit:cost ratio was the highest with the crop sown during II FN of June (S_1) which was significantly higher than that with I FN of July (S_2). The latter inturn resulted in significantly higher benefit:cost ratio than that with crop sown during II FN of July (S_3). The lowest benefit:cost ratio was with I FN of August (S_4) sown crop.

Significantly higher benefit:cost ratio of proso millet was with application of 60 kg N ha^{-1} (N_4). The next best treatment in realizing higher benefit:cost ratio was 40 kg N ha^{-1} (N_3) which was significantly higher than that of 20 kg N ha^{-1} (N_2). Significantly lower benefit:cost ratio was with no nitrogen (N_1).

Higher economic returns associated with the crop sown during II FN of June (S_1) was due to higher grain and straw yields as the crop sown during this period enjoyed all favourable weather conditions. The results from the present investigation corroborates with the findings of Ramshe *et al.* (2003).

Application of 60 kg N ha^{-1} (N_4) resulted in higher economic returns as the higher nutrient dose has met the crop needs through adequate nutrient supply which resulted in better performance of the crop. These results are similar with the findings of Arshewar *et al*. (2018).

Chapter – V

Summary & Conclusions

Chapter V

SUMMARY AND CONCLUSIONS

A field experiment entitled **"Performance of proso millet under varied times of sowing and levels of nitrogen"** was conducted during *kharif*, 2019 on sandy loam soils of dryland farm, S. V. Agricultural College, Tirupati. The experiment was laid out in split-plot design with four main plots, four sub plots and replicated thrice. The treatments consisted of four times of sowing *viz.*, II FN of June (S_1), I FN of July (S_2), II FN of July (S_3) and I FN of August (S_4) assigned to main plots and four nitrogen levels *viz.*, control (N_1), 20 kg N ha^{-1} (N_2), 40 kg N ha^{-1} (N_3) and 60 kg N ha^{-1} (N_4) allotted to sub plots.

The observations on growth parameters of proso millet *viz.*, plant height, leaf area index, dry matter production and number of tillers m^{-2} were recorded at 20, 40 and 60 DAS and at harvest; yield attributes *viz.*, number of panicles m^{-2}, length of the panicle, weight of grains $panicle^{-1}$, thousand grain weight and yield were recorded at harvest. Post harvest soil nutrient (N, P_2O_5 and K_2O) status and nutrient uptake (N, P, K) at harvest of proso millet were estimated. Economics including gross returns, net returns and benefit:cost ratio were worked out. The salient findings of the investigation are summarized below.

Significantly taller plants were observed with the crop sown during II FN of June (S_1) than that of I FN of July (S_2) at all the stages of observation, except at 20 DAS, where they were on par with each other. Short statured plants were noticed with I FN of August (S_4) sown crop. Application of 60 kg N ha^{-1} (N_4) resulted in significantly taller plants at all the stages of crop growth, compared to the lower levels of nitrogen tried. Significantly shorter plants were noticed with control (N_1).

Irrespective of time of sowing and nitrogen levels tried, leaf area index increased progressively with advance in age of the crop upto 60 DAS, beyond which decline was observed towards harvest. Comparable values of leaf area index at 20 DAS were noticed with II FN of June (S_1) and I FN of July (S_2)

sown crops. However, significant difference was noticed at later stages of observation upto harvest. Crop sown during II FN of July (S_3) resulted in significantly higher leaf area index than with I FN of August (S_4) at all the crop growth stages. Proso millet supplied with 60 kg N ha^{-1} (N_4) resulted in significantly higher leaf area index whereas the lowest leaf area index was reported with control (N_1).

At all the stages of observation, significantly higher dry matter accumulation was recorded when proso millet sowing was done during II FN of June (S_1) than that of I FN of July (S_2) except at 20 DAS. Dry matter accumulation was significantly lower with I FN of August (S_4) sown crop. Increase in the level of nitrogen resulted in increased dry matter accumulation at all stages of observation. The highest dry matter accumulation was recorded with the crop supplied with 60 kg N ha^{-1} (N_4) and the lowest dry matter production was with control (N_1).

Proso millet sown during II FN of June (S_1) resulted in higher number of tillers m^{-2} which was significantly superior to that of crop sown during I FN of July (S_2) except at 20 DAS. Number of tillers m^{-2} reduced significantly when sowing was extended upto I FN of August (S_4). Application of 60 kg N ha^{-1} (N_4) resulted in significantly higher number of tillers m^{-2} followed by that with 40 kg N ha^{-1} (N_3), 20 kg N ha^{-1} (N_2) and control (N_1) which differed significantly in the order of descent.

Delay in sowing from II FN of June (S_1) to I FN of August (S_4) significantly reduced the number of days to 50 per cent flowering. Regarding nitrogen levels, number of days to 50 per cent flowering reduced gradually with increase in nutrient dose.

The longest crop duration was with the crop sown during II FN of June (S_1) which was significantly longer than that with other sowing times. Significantly shorter duration was noticed with the crop sown during I FN of August (S_4). Number of days to maturity reduced with increase in nitrogen level. Application of 60 kg N ha^{-1} (N_4) significantly hastened maturity compared to other lower nitrogen levels. Days to maturity with application of 40 kg N ha^{-1} (N_3) and 20 kg N ha^{-1} (N_2) were statistically comparable. No nitrogen (N_1) application took significantly more number of days to reach maturity. The interaction effect between times of sowing and levels of nitrogen in influencing any of the growth parameters were not statistically traceable.

Number of panicles m^{-2} recorded with the crop sown during II FN of June (S_1) were comparable with that of I FN of July (S_2). Crop sown during I FN of August (S_4) resulted in the lowest number of panicles m^{-2}. With each increment in nitrogen dose from 0 kg N ha^{-1} to 60 kg N ha^{-1} (N_4) significant increase in number of panicles m^{-2} was noticed. Minimum number of panicles m^{-2} was recorded with control (N_1).

The higher panicle length of proso millet was with crop sown during II FN of June (S_1), which was however, comparable with that of I FN of July (S_2). While the lowest panicle length was with I FN of August (S_4) sown crop. Crop that recevied higher nitrogen level *i.e.* 60 kg N ha^{-1} (N_4) produced significantly lengthier panicles, while the shorter panicles were with control (N_1).

Significantly higher grain weight $panicle^{-1}$ and thousand grain weight were with the crop sown during II FN of June (S_1) followed by that with I FN of July (S_2), II FN of July (S_3) and I FN of August (S_4) which differed significantly in the order of descent. Significantly higher grain weight $panicle^{-1}$ and thousand grain weight were recorded when the crop was supplied with highest dose of nitrogen *i.e.* 60 kg N ha^{-1} (N_4) and their lowest were recorded with control (N_1).

Proso millet sown during II FN of June (S_1) produced significantly higher grain and straw yield than with I FN of July (S_2). Crop sown during I FN of August (S_4) resulted in significantly lower grain and straw yield. Grain and straw yield increased significantly with application of 60 kg N ha^{-1} (N_4) than with 40 kg N ha^{-1} (N_3) and the lowest grain and straw yield were recorded with control (N_1). The interaction effect between times of sowing and levels of nitrogen in influencing any of the yield parameters and yield were not statistically traceable.

Higher post harvest soil available nutrients (N, P_2O_5 and K_2O) were recorded with the crop sown during I FN of August (S_4) which was significantly superior to other early sown crops. Crop sown during II FN of June (S_1) resulted in significantly lower post harvest soil available nutrient status. Crop provided with higher nitrogen dose of 60 kg N ha^{-1} (N_4) resulted in significantly higher post harvest soil available nitrogen while it was found to be lowest with control (N_1). Post harvest soil available phosphorus and potassium were highest with control (N_1), while their significantly lower values were with 60 kg ha^{-1} (N_4).

Nutrient uptake (nitrogen, phosphorus and potassium) by proso millet at harvest was significantly higher with the crop sown during II FN of June (S_1) than with I FN of July (S_2) sown crop. The uptake of nutrients decreased gradually with delay in sowing upto I FN of August (S_4). Significantly higher nutrient uptake was due to the application of 60 kg N ha^{-1}(N_4). The lowest nutrient uptake was with control (N_1).

Gross returns, net returns and benefit:cost ratio were significantly influenced by times of sowing and nitrogen levels. The highest gross and net returns and benefit:cost ratio were realized with II FN of June (S_1) sowing which were significantly superior to that of I FN of July (S_2) sowing. The lowest gross, net returns and benefit:cost ratio were with late sown crop *i.e.* with I FN of August (S_4). Significantly higher gross and net returns and benefit:cost ratio were obtained with the application of 60 kg N ha^{-1} (N_4). The lowest gross and net returns and benefit:cost ratio were obtained with control (N_1).

The following conclusions could be drawn from the present investigation.

1. Proso millet sown during II Fortnight of June performed well and resulted in higher growth characters, yield parameters and yield indicating the suitable time for sowing of proso millet during *kharif* in Southern Agro-climatic Zone of Andhra Pradesh.

2. Proso millet responded upto 60 kg N ha^{-1} and has resulted in elevated stature of growth parameters, yield and monetary returns.

3. Though the interaction between times of sowing and nitrogen levels was not observed, crop sown during II Fortnight of June provided with 60 kg N ha^{-1} resulted in better crop performance in terms of yield and monetary returns.

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The Literature cited is as per the thesis format guidelines of Acharya N.G. Ranga Agricultural University, Guntur, Andhra Pradesh, India.

Appendices

APPENDIX – A

CALENDAR OF OPERATIONS

Operation	Times of sowing			
	II FN of June	I FN of July	II FN of July	I FN of August
Land preparation	12-06-19	12-06-19	12-06-19	12-06-19
Levelling of the field	17-06-19	17-06-19	17-06-19	17-06-19
Layout of the experimental field	21-06-19	21-06-19	21-06-19	21-06-19
Sowing and fertilizer application	26-06-19	11-07-19	31-07-19	08-08-19
Irrigation	29-06-19	14-07-19	03-08-19	12-08-19
Thinning & gap filling	08-07-19	22-07-19	12-08-19	20-08-19
Split application of urea	18-07-19	01-08-19	21-08-19	28-08-19
Irrigation	18-07-19	01-08-19	21-08-19	28-08-19
Weeding	21-07-19	05-08-19	24-08-19	03-09-19
Spraying of Chlorpyriphos	25-07-19	09-08-19	28-08-19	06-09-19
Irrigation	01-08-19	17-08-19	04-09-19	09-09-19
Weeding	14-08-19	20-08-19	11-09-19	23-09-19
Harvesting	12-09-19	24-09-19	11-10-19	17-10-19
Threshing, cleaning and drying of the produce	14-09-19	26-09-19	13-10-19	19-10-19

APPENDIX – B

COST OF INPUT AND OUTPUT

S. No.	Input/output	Unit	Unit Cost (₹)
1	Seed cost	kg	80.0
2	Urea	kg	6.0
3	Single super phosphate	kg	4.0
4	Chlorpyriphos	l	370.0
5	Proso millet grain	kg	35.0
6	Proso millet straw	kg	0.50
7	One man day^{-1}	1	250

APPENDIX – C

COST OF CULTIVATION (₹ ha^{-1}) EXCLUDING THE COST OF NITROGEN FERTILIZER

S.No.	Particulars	II FN of June	I FN of July	II FN of July	I FN of August
1	Land preparation	4250	4250	4250	4250
2	Cost of seed	800	800	800	800
3	Sowing	2500	2500	2500	2500
4	SSP	1000	1000	1000	1000
5	Thinning and Gap filling	1500	1500	1500	1500
6	Weeding	4000	4000	4000	4000
7	Irrigation	1500	1500	1500	1500
8	Plant protection	1400	1400	1400	1400
9	Harvesting, threshing and cleaning	4500	4500	4500	4500
	Total cost	21450	21450	21450	21450

APPENDIX – D

TOTAL COST OF CULTIVATION (₹ ha^{-1}) INCLUDING THE COST OF NITROGEN FERTILIZER

Treatments	Cost of cultivation excluding fertilizers	Cost of fertilizers	Total Cost of cultivation
S_1N_1	21450	0	21450
S_1N_2	21450	1260	22710
S_1N_3	21450	1520	22970
S_1N_4	21450	1780	23230
S_2N_1	21450	0	21450
S_2N_2	21450	1260	22710
S_2N_3	21450	1520	22970
S_2N_4	21450	1780	23230
S_3N_1	21450	0	21450
S_3N_2	21450	1260	22710
S_3N_3	21450	1520	22970
S_3N_4	21450	1780	23230
S_4N_1	21450	0	21450
S_4N_2	21450	1260	22710
S_4N_3	21450	1520	22970
S_4N_4	21450	1780	23230

Plates

Plate 1. Overall view of the experimental field.

Plate 2. Stature of proso millet at harvest with S_1N_4.

Plate 3. Stature of the plant at harvest of proso millet as influenced by times of sowing with 60 kg N ha^{-1}.

Plate 4. Stature of the plant at harvest of proso millet as influenced by nitrogen levels with the crop sown during II FN of June.