

**Performance of bud chip seedlings under integrated
nutrient management in autumn planted sugarcane
(*Saccharum officinarum* L.)**

A Thesis
Submitted to the
Assam Agricultural University

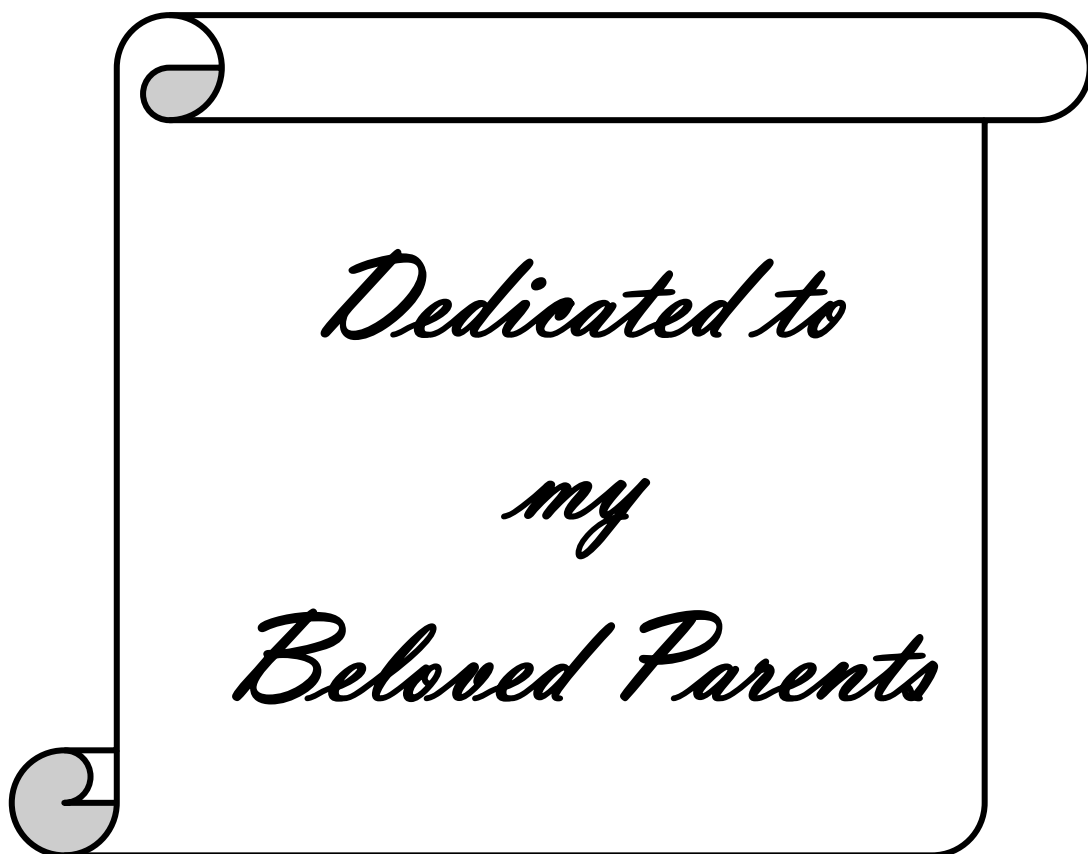
In partial fulfillment of the requirements for the degree of

**DOCTOR OF PHILOSOPHY (AGRICULTURE)
IN
AGRONOMY**



By
Mahima Begum
Regn. No. 99 of 2003
[Roll No. 2017-ADJ-14]

**DEPARTMENT OF AGRONOMY
FACULTY OF AGRICULTURE
ASSAM AGRICULTURAL UNIVERSITY
JORHAT-785 013 (ASSAM)
June, 2021**



*Dedicated to
my
Beloved Parents*

ASSAM AGRICULTURAL UNIVERSITY
FACULTY OF AGRICULTURE
JORHAT-13

CERTIFICATE – I

This is to certify that the thesis entitled “**Performance of bud chip seedlings under integrated nutrient management in autumn planted sugarcane (*Saccharum officinarum* L.)**” submitted to the Faculty of Agriculture, Assam Agricultural University in partial fulfillment for the degree of **Doctor of Philosophy (Agriculture)** in **Agronomy** is a record of research work carried out by **Mahima Begum** under my personal supervision and guidance.

All helps received by her have been duly acknowledged.

No part of this thesis has been reproduced elsewhere for any degree.

Dated: Jorhat

The, 2021

(N. J. Ojha)
Professor
Department of Agronomy
College of Agriculture
Assam Agricultural University
Jorhat – 785 013

CERTIFICATE - II

This is to certify that the thesis entitled “**Performance of bud chip seedlings under integrated nutrient management in autumn planted sugarcane (*Saccharum officinarum* L.)**” submitted by **Mahima Begum, Roll. No. 2017-ADJ-14** to the Assam Agricultural University in partial fulfillment of the requirement for the degree of **Doctor of Philosophy (Agriculture)** in the discipline of **Agronomy** has been examined and approved by the Student’s Advisory Committee and the External Examiner after viva-voce.

(N. J. Ojha)
Major Advisor

External Examiner

Members of the Advisory Committee:

1. _____
(B. C. Bordoli)

2. _____
(K. Kurmi)

3. _____
(D. D. Singha)

4. _____
(R. Das)

(B. C. Bordoli)
Professor & Head
Department of Agronomy
Assam Agricultural University
Jorhat-785 013 (Assam)

(A. Baishya)
Director
Post-Graduate Studies
Assam Agricultural University
Jorhat-785 013 (Assam)

ACKNOWLEDGEMENT

With immense pleasure the author would like to take the privilege to express her sincere gratitude to Major Advisor and chairman Dr. (Mrs.) N. J. Ojha, Professor, Department of Agronomy, Assam Agricultural University, Jorhat for her continuous support, guidance and encouragement during the entire period of experiment as well as preparation of this manuscript.

The author extends her sincere gratefulness to the members of advisory committee Dr. Bijnan Chandra Bordoloi, HoD for his support and guidance in execution of the field experiment. The author also would like show her thankfulness to other advisory members Dr. K. Kurmi, Professor, Department of Agronomy, Dr. D. D. Singha, Principal Scientist, SRS, Buralikson and Dr. R. Das, Professor, Department of Crop Physiology.

The author is highly obliged to Dr. Ajit Baishya, Director of Post-Graduate Studies, Assam Agricultural University, Jorhat for providing necessary facilities and smooth conduct of the academic programme during the course of study.

Deep sense of thankfulness goes to the entire faculty and staff members, Department of Agronomy for their co-operation, which made the investigation successful. The author also would like to extend her thankfulness to the entire field as well as staff member of SRS of Buralikson for their kind co-operation.

The author bestows her special thanks to Tarun Baruah and Rupak Gogoi for typing and composing the manuscript with care and precision within a short period of time.

The author would like to offer her thankfulness to Dr. Pranjit Sutradhar, Ms. Bhaswati Sarmah, Mr. Vishwa Jyoti Baruah, Haridra Sharma, Arifa Momtaz, Ankur Bora, Jiten Saikia, Lipika Bora for their opportune help whenever called for and constant encouragement.

The author is indebted to her father Md. Saifuddin Ahmend, Rtd teacher and mother Mrs. Sakina Begum, for their love, affection, blessings and sacrifices that always pushed her to accomplish this task. The author is obliged to her sister Mrs Monija Begum and brother Md. Farukuddin Ahmed for their moral support during the investigation. She duly acknowledges the blessing and love from her mother-in-law late Rojamai Begum, father-in-law Md. Sona Rashid. The acknowledgement would be incomplete if she does not mention the love and support offered by her husband Md. Imdadur Rashid, who stood by her side during the highs and lows of this entire programme.

Finally, the author is very much grateful to the Almighty God, who was always there to bless her with good health and strength without whom, it would be a difficult task to reach the pinnacle of success.

Dated, Jorhat

The _____2021

The Author

ABSTRACT

A field experiment entitled “Performance of bud chip seedlings under different integrated nutrient management practices in autumn planted sugarcane (*Saccharum officinarum* L.)” was conducted at Sugarcane Research Station, Buralikson, Assam for two consecutive years 2017-18 and 2018-19. The experiment consisted of three crop establishment techniques in main plot *viz.*, M₁: Conventional method of planting M₂: Planting of bud chip seedling at 90 cm x 60 cm, M₃: Planting of bud chip seedling at 120 cm x 60 cm and five integrated nutrient management practices under sub plot *viz.*, F₁: 100 % RDF, F₂: 100 % RDF + vermicompost @ 1 t ha⁻¹ + green manuring (cowpea incorporation) + biofertilizers @ 10 kg ha⁻¹ F₃: 100 % RDF + enriched compost @ 1 t ha⁻¹ + green manuring (cowpea incorporation), N₄: 75 % RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring (cowpea incorporation) + biofertilizers @ 10 kg ha⁻¹ and F₅: 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring (cowpea incorporation). The treatments were laid out in split plot design and replicated thrice. The soil of experimental plot was clay loam in texture, acidic in reaction (pH 5.46 and 5.48) and medium in organic carbon content (0.71 and 0.68%) and available K₂O (194.33 and 187.66 kg ha⁻¹), low in available N (231.42 and 226.77 kg ha⁻¹) and P₂O₅ (19.28 and 18.64 kg ha⁻¹) during 2017-18 and 2018-19, respectively.

Experimental findings revealed that the most of the plant growth parameters were significantly affected by crop establishment techniques. The planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded significantly higher values of plant growth parameters *viz.*, total number of shoots ha⁻¹, number of shoots plant⁻¹, plant height, root growth, above ground biomass, LAI, LAD and CGR throughout the crop growing period, but was *at par* with planting of bud chip seedling at 90 cm x 60 cm (M₂) in respect of physiologically active leaves plant⁻¹ and leaf area stalk⁻¹ during both the years. However, in case of few growth parameters such as chlorophyll content, green seeker NDVI, crop canopy temperature and RGR, no significant variation was observed among the crop establishment techniques.

The planting of bud chip seedling at 120 cm x 60 cm (M₃) also revealed significantly higher values of most of the yield attributing parameters such as length of millable cane, number of millable canes, number of internodes millable cane⁻¹, length of internodes, average cane weight and eventually the cane yield of both individual years

as well as in pooled analysis. Results revealed that planting of bud chip seedling at 120 cm x 60 cm (M_3) produced significantly higher cane yield for both the individual years (123.20 t ha⁻¹ during 2017-18 and 118.64 t ha⁻¹ during 2018-19) as well as in pooled analysis (120.92 t ha⁻¹). Similarly, significantly higher values of green top, trash as well as total biological yield were also obtained under the planting of bud chip seedling at 120 cm x 60 cm (M_3). The same crop establishment technique (M_3) also registered significantly higher CCS as well as jaggery yield during both the years, but did not exert any significant effect on juice quality parameters over other crop establishment techniques.

Likewise, significantly higher uptake of nutrients by different plant parts as well as the whole plant was obtained under the planting of bud chip seedling at 120 cm x 60 cm (M_3). However, no significant differences were observed in case of soil physico-chemical characteristics *viz.*, soil pH and organic carbon during both the years.

All the integrated nutrient management treatments produced significantly higher plant growth, root growth and physiological parameters over 100% RDF (F_1). Application of 100 % RDF + vermicompost @ 1 t ha⁻¹ + green manuring (cowpea incorporation) + biofertilizers @ 10 kg ha⁻¹ (F_2) produced significantly higher values in case of all the plant growth such as total number of shoots ha⁻¹, number of shoots plant⁻¹, plant height, leaf area stalk⁻¹, dry weight of above ground biomass, root growth and other physiological parameters like LAI, LAD, CGR, and RGR. But in few parameters such as number of physiologically active leaves plant⁻¹, chlorophyll content, canopy temperature and green seeker NDVI all the treatments were at par with each other except 100% RDF.

The integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring (cowpea incorporation) + biofertilizers @ 10 kg ha⁻¹ (F_2) also recorded significantly higher results in case of yield attributing characters *viz.*, length of millable cane, number of millable canes, number of internodes millable cane⁻¹, length of internodes, average cane weight and finally resulted in higher cane, green top as well as trash yield. Results revealed that the integrated application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring (cowpea incorporation) + biofertilizers @ 10 kg ha⁻¹ produced the highest cane yield for both individual years (115.46 t ha⁻¹ in 2017-18 and 111.11 t ha⁻¹ in 2018-19) as well as in pooled analysis (113.28 t ha⁻¹) which was at par with all other treatments, but superior over 100% RDF. Similarly, significantly

higher green top as well as trash were also obtained under the treatment receiving 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring (cowpea incorporation) + biofertilizers @ 10 kg ha⁻¹ (F₂) for both individual years as well as in pooled analysis. The same treatment (F₂) also recorded the significantly higher biological yield (142.08 and 136.78 t ha⁻¹), commercial cane sugar (14.62 and 13.95 t ha⁻¹) and jaggery yield (10.67 and 10.13 t ha⁻¹) during both the years. But except CCS%, the integrated nutrient management treatments failed to exert any significant effect on other juice quality parameters like field brix content, juice recovery and purity %.

The N in content in all the plant parts *viz.*, cane stalk, green top, trash and K content in cane stalk was significantly influenced by integrated management practices and maximum values were obtained due to application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂). Significantly higher N, P and K uptake by cane stalk, green top, trash as well as whole plant were also obtained under integrated application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂). All the integrated nutrient management practices significantly influenced the soil physico-chemical and biological characteristics over 100% RDF. The application of 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring (cowpea incorporation) + biofertilizers @ 10 kg ha⁻¹ (F₄) produced the highest soil organic carbon (0.85 and 0.84%), fungal (5.44 x 10⁴*cfu g⁻¹ and 5.38 x 10⁴*cfu g⁻¹) and bacterial population (6.51x10⁶*cfu g⁻¹ and 6.45 x 10⁶*cfu g⁻¹) as well as available N and P₂O₅ in soil during both the years.

The interaction effect was found to be significant in few growth parameters like total number of shoots, number of shoots plant⁻¹ and leaf area duration. The planting of bud chip seedling at 120 cm x 60 cm along with 100 % RDF + vermicompost @ 1 t ha⁻¹ + green manuring (cowpea incorporation) + biofertilizers @ 10 kg ha⁻¹ (M₃F₂) recorded the highest values in the above parameters. In case of economics the higher gross return (₹ 3, 82,906 ha⁻¹ and ₹ 3,67,546 ha⁻¹), net return (₹ 2,62,388 ha⁻¹ and ₹ 2,45,628 ha⁻¹) as well as B-C ratio (3.18 and 3.01) was also recorded under the planting of bud chip seedling at 120 cm x 60 cm along with 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring (cowpea incorporation) + biofertilizers @ 10 kg ha⁻¹ (M₃F₂) during both the years.

CONTENTS

CHAPTER NO.	TITLE	PAGE NO.
I	INTRODUCTION	1 – 5
II	REVIEW OF LITERATURE	6 – 30
III	MATERIALS AND METHODS	31 – 51
IV	RESULTS AND DISCUSSION	52 – 189
V	SUMMARY AND CONCLUSION	190 – 198
	PLATES	199 – 208
	BIBLIOGRAPHY	209 – 225
	ANNEXURE	i – x
	APPENDICES	i – xxiv

LIST OF TABLES

Table No	Title	Page No.
3.1	Physico-chemical and microbiological properties of the experimental site	34
3.2	Moisture and NPK content of organic inputs	39
3.3	Nutrient composition and contribution from green manuring of cowpea	39
4.1	Effect of crop establishment technique and integrated nutrient management on total number of shoots in sugarcane	58
4.1.1	Interaction effect between the crop establishment techniques and integrated nutrient management on total numbers of shoots ($'000 \text{ ha}^{-1}$) at 180DAP	59
4.1.2	Interaction effect between the crop establishment techniques and integrated nutrient management on total numbers of shoots ($'000 \text{ ha}^{-1}$) at 210 DAP	60
4.2	Effect of crop establishment techniques and integrated nutrient management on number of shoots plant^{-1} in sugarcane	63
4.2.1	Interaction between the crop establishment techniques and integrated nutrient management on total numbers of shoots plant^{-1} at 180 DAP	64
4.2.1	Interaction between the crop establishment techniques and integrated nutrient management on total numbers of shoots plant^{-1} at 210 DAP	65
4.3	Effect of crop establishment techniques and integrated nutrient management on number of physiologically active leaves shoot $^{-1}$ in sugarcane	69
4.4	Effect of crop establishment techniques and integrated nutrient management on plant height in sugarcane	73
4.5	Effect of crop establishment techniques and integrated nutrient management on leaf area shoot $^{-1}$ in sugarcane	77
4.6	Effect of crop establishment techniques and integrated nutrient management on leaf area index in sugarcane	82
4.7	Effect of crop establishment techniques and integrated nutrient management on leaf area duration (LAD) in sugarcane	87

Table No	Title	Page No.
4.7.1	Interaction effect between the crop establishment techniques and integrated nutrient management on leaf area duration (LAD) at 150 -210 DAP	88
4.7.2	Interaction effect between the crop establishment techniques and integrated nutrient management on total numbers of shoots plant ⁻¹ at 210-270 DAP	89
4.8	Effect of crop establishment techniques and integrated nutrient management on crop growth rate in sugarcane	93
4.9	Effect of crop establishment technique and integrated nutrient management on relative growth rate in sugarcane	99
4.10	Effect of crop establishment techniques and integrated nutrient management on chlorophyll content, green seeker NDVI and crop canopy temperature in sugarcane	104
4.11	Effect of crop establishment techniques and integrated nutrient management on root length and root dry weight of sugarcane	110
4.12	Effect of crop establishment techniques and integrated nutrient management on dry weight of above ground biomass in sugarcane	115
4.13	Effect of crop establishment techniques and integrated nutrient management on yield attributing characters of sugarcane	124
4.14	Effect of crop establishment techniques and integrated nutrient management on length of internodes and number of internodes cane ⁻¹ of sugarcane	129
4.15	Effect of crop establishment techniques and integrated nutrient management on yield of sugarcane	135
4.16	Effect of crop Effect of crop establishment techniques and integrated nutrient management on biological yield and harvest index of sugarcane	142
4.17(a)	Effect of establishment techniques and integrated nutrient management on qualitative studies (field brix) of sugarcane	147
4.17(b)	Effect of crop establishment techniques and integrated nutrient management on qualitative studies (Juice recovery, juice quality parameters and CCS yield) of sugarcane	148

Table No	Title	Page No.
4.18	Effect of crop establishment techniques and integrated nutrient management on Jaggery recovery and jaggery yield of sugarcane	154
4.19	Effect of crop establishment techniques and integrated nutrient management on nitrogen content and its uptake by plant at harvest of sugarcane	158
4.20	Effect of crop establishment techniques and integrated nutrient management on phosphorous content and its uptake by plant at harvest of sugarcane	164
4.21	Effect of crop establishment techniques and integrated nutrient management on potassium content and its uptake by plant at harvest	170
4.22	Effect of crop establishment techniques and integrated nutrient management on total nutrient uptake by plant at harvest of sugarcane	177
4.23	Effect of crop establishment techniques and integrated nutrient management on soil properties and microbial population at harvest of sugarcane	181
4.24	Effect of crop establishment techniques and integrated nutrient management on nutrient status of soil after harvest	186
4.25	Economics of crop establishment techniques and integrated nutrient management practices applied to sugarcane	188

LIST OF FIGURES

Figure No.	Title	Page No.
3.1(a)	Meteorological parameters during the crop growth period of sugarcane (2017-18)	35
3.1(b)	Meteorological parameters during the crop growth period of sugarcane (2017-18)	35
3.1(c)	Meteorological parameters during the crop growth period of sugarcane (2018-19)	36
3.1(d)	Meteorological parameters during the crop growth period of sugarcane (2018-19)	36
3.2	Layout of the experiment	41
4.1a	CGR as affected by crop establishment techniques during 2017-18	94
4.1b	CGR as affected by crop establishment techniques during 2018-19	94
4.2a	CGR as affected by integrated nutrient management during 2017-18	95
4.2b.	CGR as affected by integrated nutrient management during 2018-19	95
4.3a	RGR as affected by different crop establishment techniques during 2017-18	100
4.3b	RGR as affected by different crop establishment techniques during 2018-19	100
4.4a	RGR as affected by integrated nutrient management during 2017-18	101
4.4b	RGR as affected by integrated nutrient management during 2018-19	101
4.5a	Above ground biomass shoot ⁻¹ as affected by crop establishment techniques during 2017-18	116
4.5b	Above ground biomass shoot ⁻¹ as affected by crop establishment techniques during 2018-19	116
4.6a	Above ground biomass shoot ⁻¹ as affected by integrated nutrient management during 2017-18	117
4.6b	Above ground biomass shoot ⁻¹ as affected by integrated nutrient management during 2018-19	117

LIST OF PLATES

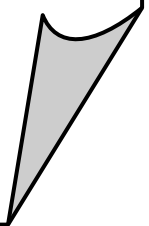
Plate No.	Title	Page No.
1	Preparation for layout for the experiment	199
2	Extraction of bud chip from cane	199
3	Shade drying of bud chip after treating with fungicidal solution	199
4	Raising of bud chip seedling in nursery	200
5	Bud chip seedling ready for transplanting	200
6	Application of organic manure in pit before transplanting the bud chip seedling	200
7	Transplanting of bud chip in main field	201
8	Transplanting of bud chip seedling close view	201
9	Sowing of cowpea as green manuring crop in between the rows of sugarcane	201
10	Tillering stage as affected by planting of bud chip seedling at 120 cm x 60 cm along with 100 % RDF + VC@ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹ (M ₃ F ₂)	202
11	Comparison of height under different crop establishment techniques 2017-18	202
12	General view of experiment during grand growth stage (2017-18)	202
13	Overall view of the experimental plot during 2017-18	203
14	Experimental field visit by Major advisor, Ex HoD and present HoD	203
15	Visual difference of plant height at maturity during 2018-19	203
16	Early grand growth stage as affected by conventional method and 100% RDF (M ₁ F ₁)	204
17	Grand growth stage as affected by conventional method and 75 % RDF + FYM @ 5 t ha ⁻¹ + vermicompost @ 1 t ha ⁻¹ + green manuring (cowpea incorporation) + biofertilizers @ 10 kg ha ⁻¹ (M ₁ F ₄)	204
18	Grand growth stage as affected by planting of bud chip seedling at 90 cm x 60 cm along with 100 % RDF (M ₂ F ₁)	204

Plate No.	Title	Page No.
19	Grand growth stage as affected by planting of bud chip seedling at 120 cm x 60 cm along with 100 % RDF + VC @ 1 t ha ⁻¹ +GM+ BF@ 1o kg ha ⁻¹ (M ₃ F ₂)	205
20	Grand growth stage as affected by planting of bud chip seedling at 120 cm x 60 cm along with 100 % RDF + EC @ 1 t ha ⁻¹ + GM (M ₃ F ₃)	205
21	Grand growth stage as affected by planting of bud chip seedling at 120 cm x 60 cm along with 75 % RDF + FYM @ 5 t ha ⁻¹ + vermicompost @ 1 t ha ⁻¹ + green manuring (cowpea incorporation) + biofertilizers @ 10 kg ha ⁻¹ (M ₃ F ₄)	205
22	Comparison of root growth between conventional method (M ₁) and bud chip seedling planting at 120 cm x 60 cm (M ₃)	206
23	Recording of number of millable cane under the treatment M ₃ F ₂	206
24	Recording of crop canopy temperature with the help of IR thermometer	206
25	Measurement of length of internodes of millable cane	207
26	Measurement of diameter of millable cane at harvest	207
27	Cane yield recorded under planting of bud chip seedling at 120 cm x 60 cm along with 100 % RDF + VC@ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹ (M ₃ F ₂)	207
28	Cane yield recorded under planting of bud chip seedling at 120 cm x 60 cm along with 100 % RDF + EC @ 1 t ha ⁻¹ + GM (M ₃ F ₃)	207
29	Early maturity stage as affected by planting of bud chip seedling at 120 cm x 60 cm along with 100 % RDF + VC @ 1 t ha ⁻¹ + GM+ BF@ 1o kg ha ⁻¹ (M ₃ F ₂)	208
30	Estimation of chlorophyll content	208
31	Estimation of phosphorus in laboratory	208

ACRONYMS & ABBREVIATIONS

%	: Per cent	Max.	: Maximum
@	: At the rate of	Min.	: Minimum
B-C ratio	: Benefit Cost ratio	Eve	: Evening
Morn	: Morning	DAT	: Days after transplanting
DAP	: Days after planting	VC	: Vermicompost
RDF	: Recommended dose of fertilizer	PSB	: Phosphate solubilizing bacteria
FYM	: Farmyard manure	EC	: Enriched compost
RD	: Recommended dose	P	: Phosphorous
VC	: Vermicompost	No.	: Numbers
N	: Nitrogen	ha	: Hectare
K	: Potassium	<i>i.e.</i>	: That is
BF	: Bio-fertilizer	kg	: Kilogram
Fig.	: Figure	m ²	: square meter
No.	: Numbers	cm	: centimeter
g	: Gram	₹	: Rupees
q	: Quintal	SE _m ±	: Standard error of mean
t	: Tonnes	CD	: Critical difference
L	: Litre		

Introduction... 



CHAPTER I

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is a perennial crop under the family poaceae known for the production of sugar as well as molasses that played a pivotal role in Indian agriculture and development of industrial economy. The crop occupies an area of 4.93 million ha with the production of 3.30 million tons having an annual average productivity of about 67 t ha⁻¹ (Anonymous, 2020). Being a crop of having potential for producing high dry matter, the development of new techniques that can produce more yield with minimum cost of production is always a matter of concern. Traditionally in India, sugarcane is grown by using stem cuttings called setts that are short cane stalks with one or more buds. In this system, depending on the variety used (Nyati, 1998), very high seed rate of 7 to 10 t ha⁻¹ are required as planting material, that comprises of about 40,000 stalk pieces having 2-3 buds (Sarala, 2017). The planting of large number of three eyed setts in every furrow results in a very strong competition among the main shoots, which in turn reduces the number of tillers per planting material used (Verma, 2004). Moreover, in conventional sugarcane cultivation, the requirement of large mass of planting material create a great problem in transportation, handling and storage of seed cane that undergoes rapid deterioration thus reducing viability of buds and subsequently their sprouting.

According to Van Dillewijn (1952) for propagation of sugarcane a small volume of tissue with a single root primordium adhering to the bud are enough to ensure germination. He also stated that cutting of one bud is sufficient as seed material under favorable growing conditions. Narasimha Rao and Satyanarayana (1974) and Ramaiah *et al.* (1977) also showed the feasibility of eliminating the internodes part of the seed piece by using only buds for commercial planting. This alternative method of planting only bud chip instead of planting 2/3 budded setts reduces the quantity of planting material and also improves the quality of seed cane. These bud chips are less bulky, easily transportable and more economical seed material (Sarala, 2017). The bud chip technology as a principle in the Sustainable Sugarcane Initiative (SSI), involves the use of less seed, less water and optimum utilization of land to achieve more yields (Biksham, 2011). The bud chip technology involves removal of sugarcane bud with

small material of the root band, grown in plant media for proper germination and finally the raised seedlings are transplanted into the main field at specific inter (1.5 m) and intra-row plant spacing (0.6 m). In the Sustainable Sugarcane Initiative (SSI), with 1.5 m row and 0.6 m plant spacing, only 13,500 buds ha⁻¹ of single buds is used to achieve 122500 -137500 millable cane ha⁻¹ (Goud, 2011). Because of requirement of only ± 1 ton ha⁻¹ of seed cane (± 250 kg ha⁻¹ bud chips) in case of single budded raised seedlings, there occurs a significant reduction of 70% in seed material as well as considerable saving in cost due to the value of the extra cane made available for milling (Nyati, 1998). Moreover, the technology was found to increase cane yield by 11 per cent over the traditional method (Hunsigi, 2001). Patnaik *et al.* (2016) also reported 32.63% higher net returns under bud chip technology than the conventional method. Rajula and Ramanjaneyulu (2014) opined that bud chip technology could be one of the most viable and economical alternatives in reducing the cost of sugarcane production.

The performance of sugarcane varies depending upon the climatic and edaphic factors. Clowes and Breakwell (1998) also opined that, the bud chip take 35 days during summer and 70 days during winter for transplanting of seedlings in main field. This signifies the importance of development of proper agronomic package based on climate, season and edaphic factors. Out of crop production technology, proper spacing and nutrient management significantly influences the yield and yield attributes of sugarcane.

In case of SSI, the wide row planting up to 1.5 m facilitated mechanization and reduced cost of cultivation. In Assam, sugarcane is grown by most of the small and marginal farmers in small fragmented land holding with poor mechanization under rainfed condition. Moreover, conventional method of growing sugarcane with 2-3 budded setts by maintaining 90 cm between row to row is a recommended practice. This necessitates the development (adoption/use) of appropriate planting techniques for production of more yields per unit area. Sarala (2017) also found more number of millable canes and cane yield with the planting of bud chip seedlings at spacing of 60:120 cm x 60 cm. Similarly, Patel and Patel (2014) also reported that 1.2 m row spacing was found to be superior over 90 cm and 1.5 m row in terms of production of number of internodes, cane length, number of millable canes and cane yield which confirm the findings of Zafar *et al.* (2010).

Row spacing has a key role in maximizing yield and improving quality of sugarcane, because it determines the optimum crop stand to obtain high yield of sugarcane. Plant spacing which is a function of inter-row and intra-row spacing, is also an important agronomic attribute in crop production, as it has effect on photosynthetically active radiation (PAR), temperature, nutrition, available moisture and plant density within the crop environment (Mashiqaa *et al.*, 2011). The number of millable stalks which is a major constituent of cane yield is also affected by row spacing. Although the closer spacing results in high plant population but obstructs the cultural operations. Contradictory results have been reported regarding the impacts of row spacing on the sugarcane yield (Yadav and Prasad, 1997; Garside *et al.*, 2002; Manimaran *et al.*, 2009). In sub tropical India, generally 90 cm is considered as optimum spacing for 3 budded setts, but, while increasing the spacing up to 120 cm and 150 cm the cane yield increased by 19.4% and 32.9%, respectively (Chakrawal and Kumar, 2013). However, very little research work has been conducted on planting geometry of sugarcane bud chip seedling.

Sugarcane being a long duration crop produces huge quantity of biomass that removes large quantity of nutrients from soil for proper growth and development. For obtaining higher productivity, high yielding crop varieties requires more amounts of nutrients for better growth and yield. Tillering which provides the optimum number of stalks needed for a good yield is known to be affected by the availability of various nutrients (Malavolta, 1994; Rao *et al.*, 1989). Therefore, proper nutrient management is also very essential for better crop growth and to obtain a good number of millable cane and high yield.

Sugarcane is an exhaustive crop and due to its continuous mono cropping with the use of only inorganic fertilizers has led to depletion of soil nutrients mainly nitrogen, phosphorus, potassium along with some micronutrients and organic carbon in soil. According to Dang *et al.* (1995) sugarcane crop producing 100 tones yield ha⁻¹ removed about 140 kg N, 34 kg P and 332 kg K from the soil. The increase use of high analysis fertilizers leads to deficiency of several micronutrients (Pathak and Ghosh, 1996) in India. Besides this, imbalance and inadequate use of some nutrients results in poor cane yield, deterioration of soil health and multiple nutrient deficiencies. This emphasized the substitution of a part of inorganic fertilizers by locally available organic sources of nutrients *viz.*, manures, green manures, crop residues, bio-fertilizers *etc.* Balanced use of both organic as well as inorganic inputs is also essential to

maintain a good soil physical, chemical and biological environment as well as sustainable crop production. The use of organic fertilizers together with chemical fertilizers improved the soil health by augmenting the soil microbial biomass as compared to the sole application of either organic or inorganic fertilizers (Kumaraswamy *et al.*, 1998; Dutta *et al.*, 2003).

Organic sources can insure adequate supply of micronutrients to meet the crop need that lead to increase fertilizer use efficiency (Singh *et al.*, 1999). Organic manure not only replenishes nutrients, but also improves the physical, chemical and biological properties of soil which enhances the performance of soil applied inputs (Vanlauwe *et al.*, 2001). Application of organic matter from organic resources as such animal manure, crop residues and green manuring has been shown to replenish soil organic carbon and improve soil fertility (Saviozzi *et al.*, 2002). Moreover, several microbial agents capable of fixing N or mobilizing P and others nutrients are becoming and vital component of integrated nutrient management system for crop production. The biological nitrogen fixing bacteria like *Acetobacter* and *Azotobacter* are the cheaper source of nitrogen are able to save about 25-30 per cent of nitrogen (Kumar and Singh, 1999). For sustainability of sugarcane, neither chemical fertilizers nor organic manures alone but their integrated use has been to be highly beneficial (Banger *et al.*, 1994). Therefore, to obtain consistent sugarcane yield an effective and appropriate integrated nutrient management package comprising of organic and inorganic components is utmost important (Gopaldasundaram *et al.*, 2011). The use of organic fertilizers together with chemical fertilizers had higher positive effect on microbial biomass and soil health as compared to the addition of organic fertilizers alone (Dutta *et al.*, 2003).

The integration of organic manures along with chemical fertilizers increased the absorption of plant nutrients *viz.*, N, P and K in both plant and ratoon crop as compared to sole application of chemical fertilizers (Bokhtiar and Sakurai, 2005). The organic matter supplied through animal manure, crop residues and green manuring replenished the soil organic carbon as well as improved the soil fertility (Saviozzi *et al.*, 2002; Srivastava *et al.*, 2009) in sugarcane. The beneficial effect of intercropping and *in situ* incorporation of green manuring crop in building up of the organic matter of the soil as well as increased efficiency of applied nutrients was also reported by Bokhtiar and Sakurai (2007). Application of integrated nutrient sources can increase the activities of soil micro-organism and available nutrient contents in soil (Saha *et al.*, 2008). Moreover, the application of FYM @ 15 t ha⁻¹ in both plant and ratoon crop could save

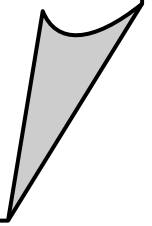
about 25% N fertilizers in sugarcane (Bokhtiar and Sakurai, 2005). They also reported significant increase the leaf nutrient content in both plant and ratoon crop under the integrated supply of organic manure along with chemical fertilizer as compared to sole application of chemical fertilizer. Besides this, integrated nutrient management found to be beneficial in improving microbial biomass and soil health (Kumaraswamy *et al.*, 1998). Thus, the integration of organic inputs like biofertilizers, green manures in sugarcane is a potential alternative strategy to prevent and to ameliorate the harmful effects of excessive inorganic fertilization on soil degradation and yield declination.

So, there is an urgent need to develop a suitable integrated nutrient management practice under the new propagation technique of growing sugarcane through bud chip seedling for sustaining cane productivity. Further, only few or very limited research has been carried out in this aspect.

Keeping this in view, an investigation on "Performance of bud chip seedlings under integrated nutrient management in autumn planted sugarcane (*Saccharum officinarum* L.)" is undertaken with the following objectives:

- 1) To evaluate the effect of different row spacing of the bud chip seedlings and integrated nutrient management on growth, yield and quality of sugarcane
- 2) To study the effect of different row spacing of the bud chip seedlings and integrated nutrient management on soil nutrient status and nutrient uptake by sugarcane

Review of Literature... ✍️



CHAPTER II

REVIEW OF LITERATURE

Sugarcane is considered as an important commercial crop for its great contribution towards development of Agricultural GDP in India. The crop has high yield potential due to which it is getting importance for development of new production technologies to maximize yield with high economic return because of many drawbacks associated with traditional cultivation practices like high requirement of planting material, poor economic return due to high cost of cultivation etc. Sugarcane is considered as an exhaustive crop because of high nutrient demand for its growth and development which in long run deteriorates soil health. Therefore, development of new technologies that can maintain good soil health and sustainability in terms of production and quality is the prime goal and objectives in present day agriculture.

Out of the recent technologies, production of sugarcane by adopting sugarcane bud chip technology is now a day's gaining importance because of its many advantages over the conventional one. The bud chip technology was developed by Indian Institute of Sugarcane Research, Lucknow, India where sugarcane bud chip seedlings were used as planting material instead of traditional 2/3 budded setts and they were planted at wider row spacing of 1.5 m and plant to plant spacing of 60 cm. However, many researchers are still working on development of location specific planting geometry for bud chip technology, nutrient management and other techniques just to maximize yield and maintain the soil health as the performance of the crop highly varies depending upon the soil, climatic condition and other crop management practices.

Since bud chip technology is a very recent technology and work done on "bud chip seedlings and integrated nutrient management" is limited, therefore, relevant research findings on other crop establishment techniques such as single budded setts, double budded sett *etc.* have also been included wherever considered necessary.

2.1 Effect of row spacing of different crop establishment techniques on performance of sugarcane

2.2 Effect integrated nutrient management on performance of sugarcane

2.3 Effect of integrated nutrient management on soil health and nutrient status

2.4 Effect of integrated nutrient management on nutrient content and uptake by plants

2.5 Effect of integrated nutrient management on economics of sugarcane

2.6 Crop establishment techniques and integrated nutrient management on growth and yield of sugarcane

2.1 Effect of row spacing of different crop establishment techniques on performance of sugarcane

2.1.1 Growth parameters of sugarcane

The success of any crop depends upon the good agronomic practices that greatly influence growth as well as yield of crop. In sugarcane, the shoot population is one of the important growth parameters that directly depend upon the row spacing under different crop establishment technique which is related to stalk height or cane length. After conducting a demonstration on bud chip technology planted at a spacing of 1.5 m x 0.60 m in farmer's field of Angul district, Odisha, India, Samant (2017) reported higher number of tillers plant⁻¹ (17.3) as compared to conventional method (9.2). The planting of bud chip settling at 120 cm row spacing produced significantly higher number of tillers m⁻² (21.0) as compared to planting at 90 (15.3) and 60 cm (13.0) row spacing (Khalid *et al.*, 2015). In another experiment, Chandrakar *et al.* (2019) also reported significantly higher number of tillers plant⁻¹ due to planting of bud chip seedling at 150 cm x 60 cm (18.00) that was at par with planting of bud chip seedling at 120 cm x 60 cm (16.33), but both of them were superior to conventional 2 budded (8.67) as well as 3 budded setts planting (6.50).

Chatta *et al.* (2007) also reported significantly higher number of tillers m⁻² (15.92) due to planting of sugarcane setts at 120 cm apart trenches that was found to be at par with 90 cm apart trenches (15.53), but significantly superior over 60 cm apart trenches (13.93) as well as 60 cm apart furrows (12.93) and 45 cm apart furrows (10.94). On the other hand, shoot population under 90 cm row spacing of 3 budded setts was found to be significantly higher as compared to 120 and 150 cm which might be due to availability of more rows per unit area under narrow spacing as compared to wider row spacing (Chakrawal and Kumar, 2013).

Further, the existence of high shoot population increased plant height as compared to low population conditions (Irvine and Benda, 1980). In general, with

increase in intra row spacing the plant height decreases and *vice versa* which is mainly due to existence of intra competition for light under high plant population. Similarly, Patel *et al.* (2002) also reported that the use of narrow row spacing caused sugarcane stalks to be longer and thinner. Lal (1988) also reported more plant height under wider spacing as compared to narrow spacing. The experiment conducted at Sugar Crops Research Institute, Pakistan, on evaluation of suitable plant spacing of sugarcane bud chip seedling revealed that although the planting of bud chip seedling at 120 cm row spacing produced more plant height (3.16 m) as compared to 90 cm spacing (3.06 m) but no significant difference was observed between them (Khalid *et al.*, 2015). Similarly, Chatta *et al.* (2007) also reported insignificant difference in plant height between planting of sugarcane setts at 90 (2.34 m) as well as 120 cm apart trenches (2.33 m), but both of them were found to be superior over planting of sugarcane at 60 cm apart trenches. The optimum availability of all resources under 120 cm row spacing might have helped in increasing the plant height. This was corroborated with the finding of Cheema *et al.* (2002). Chaudhari *et al.* (2014) also reported significantly higher plant height under 120 cm row spacing of 3 budded setts planting (298 cm) which was at par with 150 cm row spacing (297 cm), but superior over 100 cm row spacing (295 cm).

In sub-tropical India, tillering starts around 60 days after planting and it may last up to 120 days after planting. The tillering phase largely determines the productivity of sugarcane crop as the number of tillers is positively associated with number of millable canes at harvest (Roodagi *et al.*, 2001). The number of tillers varies depending upon the row spacing provided under different crop establishment techniques. Patel *et al.* (2014) reported that the planting of sugarcane setts at 120 cm row spacing significantly increased the number of tillers plant⁻¹ as well as other growth parameters such as plant height and dry matter accumulation at almost all the growth stages as compared to other row spacings. The wider spacing produced more number of tillers clump⁻¹ as well as thicker canes as compared to closer spacing (Rao, 1990). From an experiment conducted at Sugarcane Research Institute, Faisalabad, Pakistan, Chatta *et al.* (2007) reported significantly higher number of tillers m⁻² due to planting of sugarcane setts at 120 cm apart trenches (15.84) which was at par with planting of sugarcane setts at 90 cm apart trenches (15.46) but, significantly superior over 60 cm apart trenches (13.86).

The other growth parameters such as leaf area index (LAI), crop growth rate (CGR) and net assimilation rate (NAR) which are very important in assessing the

sugarcane's growth are also affected by row spacing (Khan *et al.*, 2011). After conducting an experiment on evaluation on different planting geometry on autumn planted sugarcane during 2003-04 and 2004-05, Khan *et al.* (2011) reported that planting of sugarcane setts at 30/90 paired row planting produced significantly higher crop growth rate (8.58 and 9.74 g m⁻² day⁻¹), leaf area duration (776.74 and 876.45 days) as compared to 30/120 cm paired row planting as well as 60 and 75 cm single row planting during the respective years. Several researchers reported that growth parameters were not only affected by row spacing but also greatly influenced by various planting system (Gill, 1995 and Ghaffar *et al.*, 2012). Moreover, planting of bud chip seedling at 1.5 m row spacing also recorded better expression of growth attributes *viz.*, leaf area index (6.82), plant height (340 cm) as compared to traditional method (Kumar and Suresh, 2011).

Among the different growth parameters, the green leaf area and leaf area index (LAI) are considered as important parameters for estimation of growth and yield of any crop. Leaf area index followed the similar curves in case of both plant as well as ratoon crop with slow growth in initial phase followed by faster growth in subsequent growth stages and again slowed down in maturity (Teruel *et al.*, 1997). Chakrawal and Kumar (2013) reported that the green leaf area and LAI showed an increasing trend up to 210 DAP when recorded at monthly interval under different row spacing. They reported that planting of sugarcane setts at 90 cm spacing produced maximum LAI of 2.19, 3.11, 3.78 and 4.22 at 120, 150, 180 and 210 DAP, respectively, as compared to other row spacings. The higher LAI recorded at 90 cm row spacing were due to more number of millable canes and better retention of tillers. However, towards the maturity of the crop, the increased in leaf senescence due to drying up of older leaves as well as mortality of tillers might have decreased LAI (Chakrawal and Kumar, 2013). Kumar (2020) also stated that the natural senescence of older leaves and mortality of late tillers decreased LAI towards maturity of sugarcane. Similar results were also reported by Simoes *et al.* (2005).

Ahmad (2002) also reported that wider row spacing significantly increased the leaf area tiller⁻¹ as well as LAI as compared to narrow spacing. From an experiment conducted at Sugar Crops Research Institute, Pakistan, Khalid *et al.* (2015) reported higher LAI due to planting of bud chip seedling at 120 cm row spacing (7.90) as compared to 90 cm row spacing (6.44). On the other hand, Kumar (2020) from his experiment on evaluation of optimum planting geometry for bud chip seedling in Bihar,

India, reported maximum LAI of 0.63, 2.07, 3.71 and 4.11 during April, June, August and October, respectively, of plant cane under 30:120 cm paired row, which was statistically at par with 90 cm row spacing (0.60, 2.03, 3.65 and 4.09) but superior over 120 (0.58, 1.76, 3.25 and 3.61) and 150 cm row spacing (0.48, 1.10, 2.55 and 2.91). The more plant population recorded under 30:120 cm paired row as well as 90 cm single row spacing might have increased the LAI as compared to others. However, the LAD was not affected by row spacing during all the growth stages, although the planting of sugarcane at wider row spacing of 120 cm recorded more LAD as compared to 90 cm (Rehman *et al.*, 2013)

Likewise, crop growth rate (CGR) of sugarcane also greatly decreased with narrow row spacing (30 cm) which might be due to unavailability of certain nutrients to plant roots due to more plant competition as well as mutual shading of middle and lower leaves that decreased the interception of light resulting in low photosynthetic efficiency and hence decreased crop growth rate (Datta, 2000; Khatkar and Kuhad, 2000). In this context, Ghaffar *et al.* (2012) reported significantly higher CGR in 120 cm spaced trenches ($12.68 \text{ g m}^{-2} \text{ d}^{-1}$) as compared to 90 ($11.74 \text{ g m}^{-2} \text{ d}^{-1}$) and 75 cm spacing ($11.16 \text{ g m}^{-2} \text{ d}^{-1}$). They stated that variation in total dry matter production per unit area under different trench spacings led to variation in CGR. Similarly, significantly higher CGR under wider row spacing of 120 cm as compared to 90 and 75 cm row spacing was also reported by Rehman *et al.* (2013). The production of more CGR under wider row spacing might be due to more interception of light even by the bottom leaves of sugarcane (Islam *et al.*, 2008). Ghaffar *et al.* (2012) also opined that more LAI under wider row spacing helped in more expansion of leaf area that intercepted more light and ultimately increased the CGR.

Like CGR, the planting patterns significantly influenced the net assimilation rate (NAR) of sugarcane (Chattha, 2007; Khan *et al.*, 2011). For example, the planting of sugarcane setts at 70 cm row spacing significantly increased NAR as compared to 60 cm (Khan *et al.*, 2011). The increase in NAR of sugarcane was due to an increase in leaf area and CGR (Chattha, 2007). The maximum NAR of 5.04 and 5.32 $\text{gm}^{-2} \text{ day}^{-1}$ in plant cane during June - August and August–October, respectively, was recorded due to planting of bud chip seedlings at 150 cm row spacing as compared to 90 and 120 cm (Kumar, 2020). Patil (2008) stated that optimum NAR of sugarcane was achieved at the age of 160-200 days after planting. The better availability of certain nutrients to plant roots and increased efficiency of photosynthesis might have resulted

higher values of NAR (Simoes *et al.*, 2005). Moreover, the availability of more space for air circulation and light interception might have increased photosynthetic efficiency and improved CGR, LAI, and ultimately NAR (Yadav, 1991; Khan *et al.*, 2011).

Sugarcane is known for its high potential to produce huge amount of biomass by efficiently converting the solar light energy (Naidu, 2003). This might be due more interception and distribution of light by the crop canopy which increases the photosynthesis and vegetative growth by increasing the growth parameters such as tillers, leaf area and stem biomass accumulation. Loganandhan *et al.* (2013) opined that the increase in both plant height and tiller numbers might have contributed production of more crop biomass in terms of dry matter production. The dry matter production was highly affected by CGR (Khalid *et al.*, 2009) and both of them were greatly affected by photosynthetic rates (Hunsigi, 2001). Therefore, the dry matter accumulation of sugarcane highly varies depending upon the crop planting pattern. The wider planting of sugarcane produced more dry matter as compared to narrow spacing (Cheema *et al.*, 2002). Similarly, Nadiger *et al.* (2017) reported that planting of sugarcane sets at 1.2 m spacing produced more dry matter (0.22, 2.65 and 5.77 kg m⁻² at 150, 210 DAP and at harvest, respectively) as compared to 2.4 m paired row (0.15, 1.68 and 3.78 kg m⁻² at 150, 210 DAP and at harvest, respectively) and 3.6 m paired row (0.10, 1.51 and 3.11 kg m⁻² at 150, 210 DAP and at harvest, respectively). The higher photosynthetic activity at 1.2 m spacing might have resulted in higher dry matter production as compared to other planting technique. Kumar (2020) stated that the dry matter accumulation by plant gradually increased with the advancement of crop growth. After conducting an experiment at Sugarcane Research Institute, Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, Kumar (2020) also reported significantly higher total dry matter accumulation (0.64, 8.4, 16.4, 28.4, and 31.8 t ha⁻¹ during April, June, August, October and December, respectively) under the planting of sugarcane bud chip seedling at 90 cm row spacing as compared to 120 cm, 150 cm and 30:120 paired row planting. The production of less dry matter per unit area under wider spacing might be due to less plant population.

2.1.2 Yield attributing characters

Inappropriate planting density is considered as one of the essential factor accountable for reduction in sugarcane yield (Bashir *et al.*, 2000). Sub-optimal planting density reduced the total plant population and eventually number of millable canes per

unit area as well as cane yield (Mahmood *et al.*, 2007). The planting density directly affects the yield attributing parameters like number of millable canes, cane length and diameter which are positively related to cane yield per unit area (Nazir *et al.*, 1999). Basically, cane weight or stalk weight is a function of cane thickness, cane length and cane density. Thus mean weight stalk⁻¹ decreased steadily with decrease in intra-row spacing (Orgeron, 2003). This could be ascribed to increase in population density per unit area due to the decrease in intra-row spacing. The decrease in cane weight was partially due to the decrease in cane thickness, cane height and cane density as a result of high density planting in the narrower intra-row spacing. The linear increase in cane weight cane⁻¹ with the increase in trench spacing was also reported by Ghaffar *et al.* (2012). They reported significantly higher mean weight of single cane under the planting of setts at 120 cm spacing (0.91 kg) as compared to 90 (0.83 kg) as well as 75 cm (0.77 kg). In another experiment conducted at Sant Kabir College of Agriculture and Research Station, Kawardha, Chhattisgarh, India, Chandrakar *et al.* (2019) revealed that planting of bud chip seedling of sugarcane at 120 cm × 60 cm produced significantly higher single cane weight (1.86 kg) as compared to 3 budded setts planting (1.30 kg). The more cane weight under wider spacing than the narrower spacing was also reported by Raskar and Bhoi (2003). Similar observation was also reported by Hunsigni (1993).

Row spacing under different crop establishment techniques also significantly influenced the stalk or cane length of sugarcane. Ehsanullah *et al.* (2011) reported that planting of sugarcane setts at 90 cm double row strips (2.32 m) produced significantly higher cane length that was found to be at par with 120 cm spaced 3-row strips (2.28 m). They also reported insignificant difference in cane length due to planting of 3 budded setts at 120 cm (2.36 m) as well as 90 cm spaced trenches (2.34 m). While, Ghaffar *et al.* (2012) reported significant increase in cane length at 120 cm wider trench planting (2.23 m) as compared to 90 cm single trench planting (2.02 m). After conducting an experiment at Central Sugarcane Research Station, Maharashtra, India for evaluating the suitable spacing of 3 budded setts under spring planted sugarcane, Chaudhari *et al.* (2014) also reported that 120 cm row spacing produced significantly higher length of millable cane (2.98 m) which was at par with 150 cm (2.97 m) but superior to 100 cm row spacing (2.95 m).

Like all other yield attributing characters, cane girth is also related to plant density which is governed by row as well as plant spacing. The lower plant density produced thicker canes as compared to high plant density (Ahmad *et al.*, 2011).

The planting of sugarcane bud chip seedling at 150 cm row spacing reported significantly higher cane diameter (2.13 cm) at harvest which was at par with 120 cm (2.10 cm) but found to be superior over 90 cm row spacing (2.06 cm) (Kumar, 2020). The planting of bud chip seedling at 150 cm x 60 cm spacing also enhanced the single cane weight (1.80 kg cane⁻¹) as compared to planting of single (1.09 kg cane⁻¹) and double budded setts (1.63 kg cane⁻¹) (Sugeerthi *et al.*, 2018). Kumar and Suresh (2011) also reported more cane girth (3.36 cm) as well as single cane weight (2.36 kg) under the planting of bud chip seedling at a spacing of 150 cm x 60 cm as compared to traditional method. Chandrakar *et al.* (2019) also reported significantly higher cane girth due to planting of bud chip seedling at 120 cm x 60 cm spacing (9.17 cm) that was at par with planting of bud chip seedling at 150 cm x 60 cm (8.87 cm) but superior to conventional 2 budded as well as 3 budded setts planting (7.33 cm).

They also reported significantly higher single cane weight under the planting of bud chip seedling at 150 cm x 60 cm (1.90 kg) that was at par with planting of bud chip seedling at 120 cm x 60 cm spacing (1.86 kg) but, both of them were found to be superior to the conventional 2 budded (1.19 kg) as well as 3 budded setts planting (1.30 kg). Thus increase in cane girth or diameter led to increase in cane weight and ultimately increased the cane yield per unit area (Nosheen and Ashraf, 2003). The higher cane girth under wider row spacing might be due to better availability and utilization of all resources and more competition due to higher plant population per unit area under narrow spacing might have reduced the cane girth.

Number of millable cane is one of the considerable yield attributing characters that greatly influences the cane yield. Preecha (2006) reported that the number of millable cane that directly correlated to sugarcane yield was significantly influenced by plant spacing. Netsanet *et al.* (2014) also reported more number of millable canes under high density planting as compared to low density planting. The higher number of millable canes per unit area due to planting of sugarcane setts under wider row spacing was also reported by Cheema *et al.* (2002). In case of spring planted sugarcane, planting of sugarcane setts at 120 cm spacing recorded significantly higher number of millable cane (89.63 '000 ha⁻¹) as compared to planting at 100 cm (84.54 '000 ha⁻¹) and 150 cm (85.34 '000 ha⁻¹) (Chaudhari *et al.*, 2014). Besides this, Samant (2017) also reported more number of millable cane clump⁻¹ (14.2) under the bud chip method as compared to conventional method (8.5).

The planting of bud chip seedling at 120 cm row spacing recorded significantly more number of internodes tiller⁻¹ (12.13) which was statistically at par with planting at 90 cm row spacing (10.86), but significantly superior over 60 cm row spacing (10.33) under agro ecological condition of District Mardan, Khyber Pakhtunkhwa, Pakistan (Khalid *et al.*, 2015). On the other hand, after conducting an experiment at Central Sugarcane Research Station, Padegaon, India, Choudhary *et al.* (2014) reported insignificant difference in number of internodes tiller⁻¹ under different planting geometry. Khalid *et al.* (2015) also reported that planting of bud chip seedling at 120 cm row spacing produced higher length of internode (11.73 cm) as compared to 90 (10.74 cm) and 60 cm row spacing (10.67 cm). They stated that although length of internode was a varietal character, but it was also influenced by better crop management practices. The proper orientation of plants in 120 cm row spacing might be responsible for production of higher number of internodes tiller⁻¹. The significant increase in internode length due to planting of bud chip seedling at 120 cm row spacing (14.53 cm) over both conventional 2 budded (13.20 cm) as well as 3 budded methods (12.73 cm) was also reported by Chandrakar *et al.* (2019)

2.1.3 Cane yield and harvest index

The planting geometry significantly influences the cane production in sugarcane, hence improper row spacing is considered as the most critical factor for reduction in cane yield (Mahmood *et al.*, 2007). Saini *et al.* (2012) stated that sugarcane yield could be obtained 117.8- 120.8 tons/ha by transplanting bud chips seedling with proper row spacing. Planting of sugarcane bud chip seedlings at 120 cm produced the highest cane yield (80.9 t ha⁻¹) followed by 90 cm (80.2 t ha⁻¹) and 60 cm row to row spacing (Munsif *et al.*, 2015). Similar, finding was also reported by Khalid *et al.* (2015). They also reported the highest cane yield with the planting of bud chip seedling at 120 cm row spacing (92 t ha⁻¹) followed by 90 cm (84 t ha⁻¹) and 60 cm row spacing (77 t ha⁻¹). Chaudhari *et al.* (2014) also reported significantly higher cane yield (122.33 t ha⁻¹) under 120 cm row spacing in case of spring planted sugarcane that was found at par with the 150 cm row spacing (116.89 t ha⁻¹). Mahadevaswamy and Martin (2002) also reported higher cane yield under wider row spacing as compared to narrow spacing.

Likewise, Rehman *et al.* (2013) also reported significantly higher cane yield (96.67 t ha⁻¹) with the planting of bud chip seedling at 120 cm apart as compared

to planting at 90 (85.05 t ha⁻¹) as well as 75 cm row spacing (78.85 t ha⁻¹). In this context, while evaluating the suitable planting geometry of sugarcane bud chip seedling under plant-ratoon system at Sugarcane Research Institute, Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar during 2013-16, Kumar (2020) reported significantly higher cane yield (86.4 t ha⁻¹) under the planting of bud chip seedling at 90 cm row spacing as compared to 120 (73.7 t ha⁻¹) and 150 cm (64.7 t ha⁻¹) spacing. The planting of bud chip seedling at 150 cm x 60 cm also registered significantly higher cane yield (148.56 t ha⁻¹) as compared to traditional method (Kumar and Suresh, 2011). Samant (2017) reported 39.7% higher cane yield under the planting of bud chip seedling at 150 cm x 60 cm as compared to conventional method. Earlier, Tianco (1995) also reported about 34% increase in weight of cane under the system of transplanting seedling in comparison to traditional 3 budded setts.

While conducting an experiment at Chhattisgarh to evaluate the suitable planting geometry of bud chip seedling in case of autumn planted sugarcane, Chandrakar *et al.* (2019) also reported significantly higher cane yield (160.67 t ha⁻¹) due to planting of bud chip seedling at 120 cm x 60 cm as compared to conventional 2 or 3 budded setts and other planting geometry. The optimum plant population due to sufficient spacing helped in efficient utilization of all resources and also reduced the inter-intra specific competition among the plants that resulted in higher cane yield under the planting of bud chip seedling at 120 cm x 60 cm spacing. Chattha *et al.* (2004) also reported about 30% more cane yield due to planting of 3 budded setts at wider row spacing (120 cm) as compared to narrow row spacing (60 cm). Similarly, after conducting an experiment at Patuli Sahi village of Odisha, Mohanty *et al.* (2014) also found higher cane yield (105.00 t ha⁻¹) due to planting of bud chip seedling at 120 cm x 60 cm spacing as compared to conventional method of planting (89.00 t ha⁻¹). Soomro *et al.* (2009) opined that inter row spacing greatly influenced the cane yield. They stated that the row spacing of 1.25 m was found to be the best for obtaining maximum cane yield (143.03 t ha⁻¹). Thus, maintenance of optimum crop stand by following proper spacing is considered to be a vital factor for obtaining higher cane yield. On the other hand, many researchers reported higher cane yield from narrow spacing *i.e.* 90 and 60 cm as compared to wider spacing *i.e.* 130, 140 and 180 cm (Sharma, 1984; Misra *et al.*, 1990).

The production efficiency of a crop is expressed in terms of harvest index which was greatly affected by planting pattern. Mahmood *et al.* (2007) reported

maximum harvest index up to 82.17% with planting of sugarcane setts in 100 cm spaced double-row ditches. While, Ehsanullah *et al.* (2011) reported significant difference in harvest index due to planting of sugarcane under different row spacing. They reported significantly higher harvest index (82.84%) due to planting of sugarcane setts at 90 cm spaced 2-row strips as compared to 60 cm spaced single row (81.53%) as well as 120 cm spaced 3-row strip (80.58%). While, Maqsood *et al.* (2005) reported that the harvest index was not affected by different planting patterns.

2.1.4 Juice quality

Several scientists reported various results in juice quality parameters due to row spacing under different crop establishment techniques. Khalid *et al.* (2015) reported that planting of bud chip seedling under different row spacing did not exert any significant effect on quality parameters such as brix and commercial cane sugar (CCS) content (%), pol as well as sugar recovery %, however, higher values of these parameters were recorded when bud chip seedlings were planted at 120 cm and 90 cm row spacing, respectively, as compared to 60 cm. Similarly, Chandrakar *et al.* (2019) also reported that juice quality parameter like brix and pol % were not significantly affected by planting of bud chip seedling under different planting geometry. Bokhtiar and Sakurai (2005) also reported insignificant difference in juice quality parameters such as brix, pol as well as purity % of cane juice. Maqsood *et al.* (2005) also stated that CCS % was not significantly affected by row spacing in sugarcane. Shukla and Lal (2003) also reported that the planting method did not influence on juice quality parameters. Similarly, Chaudhary *et al.* (2014) reported that planting of sugarcane setts under row spacing did not show any significant effects on quality parameters of sugarcane. However, they reported significantly higher CCS yield (17.42 t ha^{-1}) due to planting of sugarcane setts at 120 cm row spacing which was found to be at par with 150 cm (16.50 t ha^{-1}) but superior to 100 cm row spacing (16.43 t ha^{-1}). The experiment conducted by Nadiger *et al.* (2017) at K. J. Somaiya Institute of Applied Agricultural Research revealed insignificant difference in quality parameters of sugarcane *i.e.* brix, pol, purity and CCS content (%) in juice under different row spacings.

On the other hand, after conducting the experiment at Vasantdada Sugar Institute, India, Pawar *et al.* (2005) reported significantly higher CCS content (14.25%) and sugar yield (17.69 t ha^{-1}) due to planting of sugarcane settling at 60 cm spacing as compared to other row spacing as well as two budded sett planting. While,

some researchers reported that wider row spacing (120 cm) significantly enhanced the juice quality parameter like brix % (Singh *et al.*, 2011) and pol % in cane juice (Mahmood *et al.*, 2007; Ehsanullah *et al.*, 2011). On other contrary, from earlier experiment, Thomas *et al.* (1977) reported that narrow spacing significantly increased brix, pol and purity content (%) of juice as compared to wider row spacing.

2.1.5 Economics of sugarcane

Many researchers reported about 80% saving of sugarcane seed material by weight due to adoption of bud chip technology instead of conventional 3 budded setts (Narendranath 1992; Iqbal *et al.*, 2002) while ensuring the maximum net returns. The improved practice of bud chip method of sugarcane planting recorded higher gross return (₹ 271320 ha⁻¹), B-C ratio (3.86) and profitability (₹ 609.6 ha⁻¹ day⁻¹) with supplementary net return of ₹ 190080 ha⁻¹ than conventional method of cultivation (Samant, 2017). The more cane production under the bud chip technology resulted in higher B-C ratio and net return as compared to conventional method (Samant, 2017). The variation in net return and benefit-cost ratio may be attributed to the variation in the price of agricultural inputs and produce (Kapur *et al.*, 2011). Sugeerthi *et al.* (2018) also reported that planting of bud chip seedling at 150 cm x 60 cm was found to be economical in terms of net income (₹ 183,040 ha⁻¹) and B- C ratio (2.63) as compared to traditional method. Planting of bud chip seedling at spacing of 120 cm x 60 cm also recorded maximum net return (₹ 396450.00) and B-C (4.73) as compared to conventional 2 budded and 3 budded setts planting as well as other spacings (Chandrakar *et al.*, 2019). Mohanty *et al.* (2014) stated that planting of sugarcane bud chip seedling at spacing of 120 cm x 60 cm recorded higher net return (₹ 84,300 ha⁻¹) as compared to conventional method (₹ 30,950 ha⁻¹). The reduction in cost of cultivation and production of more cane yield under wider row spacing maximized the net returns (Rajulashanthy and Muthusamy, 2012).

2.2 Effect of integrated nutrient management on performance of sugarcane

2.2.1 Growth parameters

Integrated nutrient management is the key factor that greatly influenced the growth as well as some physiological parameters of sugarcane. Out of different crop growth parameters plant height is considered as an important growth parameter that determined the length of millable cane that is greatly affected by the integrated nutrient management practices. Swamy *et al.* (1999) found that the integrated use of 100%

inorganic fertilizers along with biofertilizers significantly recorded higher plant height (226 cm) which was found to be at par with the application of 50% N and P along with biofertilizers (221 cm), but found to be superior over sole application N and P fertilizers. No significant difference in plant height was recorded due to integrated application of biofertilizers along with 50% RDF and 100% RDF, respectively, although an increasing trend in plant height was recorded under integration with 100% RDF as compared to 50% RDF (Kumar and Singh, 1999). On the contrary, the integrated use of FYM and 100% RDF recorded significantly higher plant height (209 cm) than the sole application of FYM (198 cm) and chemical fertilizers (202 cm) (Sharma *et al.*, 2006). Experiment conducted at Regional Research Station, Karnal, India, revealed that the integrated application of FYM @ 10 t ha⁻¹ and bio-fertilizers along with 100% recommended dose of NPK also increased the cane length (2.91 m) over the sole application of 100% NPK (Kumar *et al.*, 2019). The integration of biofertilizers *viz.*, *Azotobacter* + *Azospirillum* and 25% RDN through FYM along with 75% RDN through inorganic fertilizer also produced significantly more cane length (220 cm) than the 100% RDF (209 cm) through inorganic source alone (Baneerje *et al.*, 2018).

In sugarcane, the tiller population dynamics is greatly affected by the stages of crop growth and a significant variation is observed from tillering stage to maturity. The number of tillers sharply increased from March onwards which attained peak stage in April and started reducing during June and after that it gradually reduced under all the nutrient management practices (Bokhtiar and Sakurai, 2005). The reduction in tiller population at later stage of crop might be due to occurrence of more competition among the tillers for nutrients, moisture *etc.* resulting in senescence of tillers at faster rate (Singels and Smit, 2002). In another experiment, Bokhtiar *et al.* (2015) also reported that total number of shoots developed under the integration of organic sources of nutrients along with RDF or 75% RDF was statistically at par with RDF. The integrated use of inorganic fertilizers and biofertilizers (*Acetobacter* + *Azotobacter* + *Azospirillum*) recorded maximum tiller or shoot population (172.24 '000 ha⁻¹) which was at par with combined use of 50% RDF along with biofertilizers (168.17 '000 ha⁻¹) but significantly superior over control (Kumar and Singh, 1999).

The application of 100% recommended dose of NK and 75% recommended dose of P along with inoculation of sugarcane setts with phosphobacterium and *in situ* green manuring of *dhaincha* reported the maximum shoots

(169.067 '000 ha⁻¹) over 100% RDF (Jeyaraman and Alagudural, 2003). After conducting an experiment at Sugarcane Research Institute, Shahjahanpur, UP, India, Yadav *et al.* (2018) also reported significantly higher number of shoots (165.28 '000 ha⁻¹) under the integrated application of FYM or compost @ 10 t ha⁻¹ and biofertilizers (*Azotobacter* + PSB) @ 12.5 kg ha⁻¹ each along with 100% RDF as compared to 100% RDF (148.96 '000 ha⁻¹).

Leaf area index (LAI) is an important parameter for determining the interception of solar radiation by the crop for photosynthesis that leads to formation of crop biomass. The leaf area index increased very sharply up to 240 days after planting (DAP), thereafter, it decreased slowly until harvest (Bokhtiar and Sakurai, 2005; Banerjee *et al.*, 2018). While conducting an experiment at Agricultural Research Station, Sankeshwar, Karnatka, India on effect of different nutrient sources, it was found that the integrated application of 100% RDF along with FYM @ 25 t ha⁻¹, biofertilizers like *Azospirillum* and PSB @ 10 kg ha⁻¹ each and micro nutrients FeSO₄ and ZnSO₄ @ 25 kg ha⁻¹ recorded significantly higher LAI (4.11) at 180 DAP and at harvest (3.04), which was found to be better as compared to 100% supply of nutrients either through organics or inorganic sources (Sridevi *et al.*, 2016). The experiment conducted at Bangladesh Sugarcane Research Station, revealed that combined application of the pressmud @ 15 t ha⁻¹ along with 75% RDF recorded the highest LAI (5.28) that was found to be superior to 100% RDF (4.53) (Bokhtiar *et al.*, 2015). Similarly, while conducting an experiment on effect of different integrated nutrient management on sugarcane at Nadia, West Bengal during 2013-16, Banerjee *et al.* (2018) reported that application of 25% RDN through FYM along with the inoculation of biofertilizers (*Azotobacter* + *Azospirillum*) and 75% RDN through inorganic fertilizers recorded maximum LAI (5.46) at 240 DAP which was significantly superior over 100% RDN (4.00).

Application of biofertilizers along with RDF @ 250:115:115 NPK kg ha⁻¹ recorded the highest leaf area (47.3 dm⁻² plant⁻¹) at grand growth stage of sugarcane over the sole application of RDF (Swamy *et al.*, 1999). Similarly, Jamuna *et al.* (2002) also reported the highest LAI with the integration of 100% RDF with biofertilizers (*Azotobacter* + PSB) (4.12) followed by application of 75% RDF + biofertilizers (3.16) and both of them were found to be superior over the control (2.07). Application of 75% RDF in combination with of pressmud @ 20 t ha⁻¹ recorded significantly higher leaf area plant⁻¹ (5840 cm²) and LAI (10.51) that were found to be at par with 100% RDF

(5481 cm², 9.87, respectively) (Soomro *et al.*, 2013). The same treatment also reported the highest crop growth rate (CGR) (10.35 g m⁻² day⁻¹) and dry matter (5542 g m⁻²) which were significantly superior over 100% RDF (9.11 g m⁻² day⁻¹, 4880 g m⁻², respectively). Kuri and Chandrasekhar (2015) also reported that integrated application of FYM @ 25 t ha⁻¹ + biofertilizers (*Azospirillum* + PSB @ 10 kg ha⁻¹ each) + 100% RDF (chemical fertilizers (N:P₂O₅:K₂O @ 250:75:190 kg ha⁻¹, respectively) recorded significantly higher CGR (20.26 g m⁻² day⁻¹) as compared to 100% RDF (17.37 g m⁻² day⁻¹). The higher growth rate of sugarcane under integrated nutrient management was mainly due to the enhanced uptake of N, P and K (Nasir *et al.*, 2000).

The dry matter accumulation per unit area highly depends upon the growth stages of sugarcane. Banerjee *et al.* (2018) reported that the dry matter production was found to be very slow at early growth stage (120 DAP) that greatly increased with advancement of growth stages of sugarcane. They also reported that dry matter accumulation sharply increased up to 240 DAP following a gradual increment till maturity and about 62–64% of the total dry-matter was produced between 120 and 240 DAP. They also reported that application of 75% RDN through inorganic fertilizers along with the addition of 25% RDN through FYM and biofertilizers recorded the highest dry-matter accumulation (511.70 t ha⁻¹) at harvest, whereas, the lowest was recorded under control plot (301.50 t ha⁻¹). Bokhtiar *et al.* (2015) also reported significant variation in dry matter production due to different integrated nutrient management practices. They reported significantly higher dry matter production (3.71 kg m⁻²) under integrated supply of 75% inorganic fertilizer + pressmud @ 10 t ha⁻¹ which was statistically at par with the treatment receiving 100% RDF (3.32 kg m⁻²).

Belowground bio-metric observations mainly include length and weight of the roots. While evaluating the performance of integrated nutrient management on growth and productivity of maize, Abid *et al.* (2020) reported that addition of organic manures such as FYM or pressmud along with NPK significantly increased the root length over 100% NPK throughout the crop growing stages of maize. However, the maximum root length was obtained under the integrated supply of FYM @ 8.5 t ha⁻¹ along with NPK. After conducting an experiment at NBPGR, New Area Farm, IARI, New Delhi during 2007-08 and 2008-09, Meena *et al.* (2013) reported that treatment receiving 75% RDF + FYM + BF + Zn recorded maximum root dry weight of 1.00 g plant⁻¹ in wheat during 2007-08 at 45 DAP, while, treatment receiving RDF + FYM + BF + Zn recorded the highest root dry weight (0.99 g plant⁻¹) during 2008-09 and both

of them were found to superior to 100% RDF (135 kg N + 60 kg P₂O₅ + 60 kg K₂O) (0.69 and 0.76 g plant⁻¹) in the respective years. Similarly, at 90 DAS, highest root dry weight (2.73 and 2.74 g plant⁻¹) was observed with RDF + FYM + BF + Zn during both the years of investigation which was significantly higher over 100% RDF only. They also reported that treatment receiving RDF + FYM + BF + Zn registered significantly higher root length in both 45 (22.8 and 21.90 cm) and 90 DAP (45.6 and 46.90 cm) over treatments receiving RDF only during both the years. In earlier experiment, Banwasi and Bajpal (2001) reported that combined application 50% NPK + 50% N through green manure in rice significantly increased the root dry weight of rice (0.55 g hill⁻¹) which was found to be at par with 100% RDF (0.53 g hill⁻¹) but found superior to other treatment combinations.

Estimation of chlorophyll content is very important for determining the photosynthesis efficiency of crop as well as plant health. The nutrients mainly Mg and N are responsible for formation of chlorophyll in leaves which was influenced by soil nutrient management practices. The integrated nutrient management practices *i.e.* application of bio fertilizers, FYM along with recommended dose of nutrients N, P₂O₅ and K₂O @ 500:170:127 kg ha⁻¹ enhanced plant growth, total chlorophyll content and nitrate reductase activity of sugarcane on vertisols (Nazirkar and Kamthe, 2012). The application of chopped trash @ 8 t ha⁻¹ and biofertilizers *viz.*, PSB, *Azotobacter*, *Acetobacter* and *Azospirillum* along with RDF significantly increased the total chlorophyll content (1.86 mg g⁻¹) as compared to control (0.92 mg g⁻¹) as well as RDF (1.11 mg g⁻¹) (Nazirkar *et al.*, 2010). Similarly, the combined use of 75% RDN through chemical fertilizer along with FYM and biofertilizers reported an increasing trend in chlorophyll a, chlorophyll b and total chlorophyll as compared to 100% RDN through inorganic fertilizer (Banerjee *et al.*, 2018). An experiment conducted by Bokhtiar *et al.* (2015) at Bangladesh Sugar Crop Research Institute, Ishurdi, Pabna, Bangladesh, revealed significant variation in chlorophyll content among the various nutrient treatments. They found that application of pressmud enriched by *Trichoderma viride* @ 7.5 t ha⁻¹ along with 100% RDF recorded significantly higher chlorophyll content in leaves (2.58 mg g⁻¹) that was found to be at par with 100% RDF (2.06 mg g⁻¹).

2.2.2 Yield attributing characters

The yield attributing characters played an important role in determining the cane yield of sugarcane. The yield attributing characters mainly include number of

millable canes, cane girth, number of internodes cane⁻¹, single cane weight, cane length etc. Zende *et al.* (1998) reported significantly higher cane girth (10.5 cm) and number of internodes cane⁻¹ (22.5) due to the application of 5 t ha⁻¹ of vermicompost along with 75% RDF as compared to RDF alone. From an experiment conducted at research farm of Regional Research Station, CCS Haryana Agricultural University, Karnal, India, Kumar *et al.* (2019) reported that application of FYM @ 15 t ha⁻¹ along with 100% RD of NPK significantly increased the yield attributing parameters *viz.*, cane girth (2.73 cm), cane length (2.97 m), single cane weight (0.92 kg) and number of millable canes (101.399 '000 ha⁻¹) over recommended dose of NPK (2.44 cm, 2.67m and 97.223'000 ha⁻¹, respectively). In another experiment, application 100% RDF along with the incorporation of *dhaincha* at 60 days and *phospho-bacterium* culture @ 10 kg ha⁻¹ reported the highest number of millable canes up to 133,660 ha⁻¹ in sugarcane (Jeyaraman and Alagudural, 2003). Similarly, while conducting an experiment at Agriculture Research Institute, Tandojam, Pakistan, Soomro *et al.* (2013) also reported significantly higher cane girth (2.63 cm), number of internodes plant⁻¹ (16.99), length of internode (13.33 cm) and number of millable canes (120.0 '000 ha⁻¹) under the combined application of 75% RDF + FYM @ 20 t ha⁻¹ which was statistically at par with combined application of 75% RDF + pressmud @ 20 t ha⁻¹ but found to superior over 100% RDF.

The beneficial effects of INM on yield attributing characters were also reported by Banerjee *et al.* (2018). After conducting an experiment at Nadia, West Bengal for three consecutive years in spring planted sugarcane they found that application of N through inorganic fertilizers along with FYM and biofertilizers significantly increased the yield attributes as compared to the application of inorganic form of N fertilizer alone. Among the treatments, application of 75% RDN through inorganic + 25% RDN through FYM + *Azotobacter* + *Azospirillum* recorded the highest number of millable canes (73,180 ha⁻¹), cane length (220 cm), single cane weight (0.85 kg) and cane diameter (2.39 cm) that were found to be superior over 100% RDN through inorganic.

From the experiment conducted at Regional Agricultural Research Station, Anakapalle, India, on clay loam soil in sugarcane plant-ratoon system, Lakshmi *et al.* (2011) reported that application of vermicompost along with RDF recorded the highest number of millable canes in both plant (94,458 ha⁻¹) as well as ratoon crop

(86,450 ha⁻¹) which was found to be significantly superior over RDF alone (88,166 and 81,423 ha⁻¹, respectively).

2.3.3 Cane yield

Cane yield is a function of yield attributing characters such as number of millable canes (NMC), single cane weight, length of internode and cane diameter at harvest *etc.* Gana and Busari (2006) reported that application of FYM in combinations with other nutrients improved the growth as well cane yield as compared to sole application of NPK fertilizer. Similarly, Kumar and Verma (2002) also reported that integrated application of FYM along with recommended dose of NPK recorded significantly higher cane yield (59.20 t ha⁻¹) which was found to be at par with the treatment receiving recommended dose of NPK along with green manuring. The beneficial effect of FYM @ 10 t ha⁻¹ along with 100% RDF over 100% RDF was also reported by Gangwar and Sharma (1998). The beneficial effect of FYM on cane yield was also reported by Sharma *et al.* (2005).

On the other hand, Yaduvanshi *et al.* (1985) opined that green manuring did not influence the yield of neither plant cane nor the subsequent ratoon crop. However, the combined application of organic sources of nutrients *i.e.* biofertilizers along with chemical fertilizers improved the cane yield and the effect was more pronounced at lower fertilizer level (50% NPK) than at higher level (75% NPK). The cane yield recorded under the application of organic manures like compost, enriched pressmud and biofertilizers along with either 50 or 75% NPK was found to be at par with application of 75 and 100% NPK through chemical fertilizers (Rakkiyappan *et al.*, 2001).

Patel and Chaudhari (2018) also reported that integration of chemical fertilizers along with organic and biological sources of nutrients was found to be better as compared to inorganic fertilizer alone. They revealed that integration of FYM @ 10 t ha⁻¹ and biofertilizers (*Acetobacter* + PSB) along with inorganic fertilizer (NPK) on soil test basis recorded more cane yield (125 t ha⁻¹) in plant-ratoon system as compared to other nutrient combinations. While evaluating the effect of integrated nutrient management on plant-ratoon system of sugarcane, Kumar *et al.* (2016) reported that the treatment receiving 100% NPK + 25% N through FYM + *Azotobacter* produced the highest cane yield of 89.8 t ha⁻¹ in plant crop and the application of 100% of recommended NPK + trash incorporation + *Azotobacter* produced the highest cane yield

of 78.0 t ha⁻¹ in ratoon crop and both of them were found to be significantly superior over 100% RDF (84.3 and 72.2 t ha⁻¹, respectively). Tyagi *et al.* (2012) also reported 27.7% increase in plant cane yield due to the application of 100% NPK + 25% N (FYM) + biofertilizers (*Azotobacter* + PSB) as compared to 100% NPK alone through inorganic fertilizers. The increase in cane yield might be due to better utilization of applied inorganic fertilizers in combination with organic manures and biofertilizers than inorganic fertilizer alone. The beneficial effect of FYM might be due to improvement in soil properties such as soil aeration, permeability, aggregation, water-holding capacity and biological properties, thereby enhancing the nutrient use efficiency and ultimately leading to better plant growth (Paikaray *et al.*, 2011).

In another experiment, the integrated use of 25% RDN through FYM + *Azotobacter* + *Azospirillum* inoculation along with 75% RDN through inorganic fertilizers produced the maximum cane yield (86.10 t ha⁻¹) which was significantly superior over 100% RDN (65.79 t ha⁻¹) (Banerjee *et al.*, 2018).

The combined application of FYM @ 10 t ha⁻¹, biofertilizers and 100% recommended dose of NPK recorded significantly higher cane yield (87.98 t ha⁻¹) as compared to 100% recommended dose of NPK (75.84 t ha⁻¹) (Kumar *et al.*, 2019). The maximum cane yield of both plant (113.10 t ha⁻¹) and ratoon crop (98.84 t ha⁻¹) under the integrated supply of FYM or compost @ 10 t ha⁻¹, biofertilizers (*Azotobacter* + PSB) @ 12.5 kg ha⁻¹ along with inorganic fertilizers on the basis of soil test as compared to 100% RDF (82.64 and 83.56 t ha⁻¹, respectively) was also reported by Yadav *et al.* (2018). The significant increase in cane yield due to the combined application of FYM, biofertilizers along with inorganic fertilizers as compared to inorganic fertilizer was also reported by Durai and Devaraj (2003). The application of biofertilizers like *Azotobacter* and *Acetobacter* was able to save 25 to 30% of nitrogen and increased the yield up to 15% in sugarcane (Kumar and Singh, 1999). After conducting an experiment at CCS, Haryana to evaluate the effect of integrated nutrient management in sugarcane, Kumar and Chand (2013) reported that inclusion of organic manures such as FYM or pressmud cake or green manure along with recommended dose of NPK produced 3–5% higher yield in plant and 5-8% in subsequent ratoon crops than the NPK alone.

2.2.4 Juice quality and sugar yield

The analysis of the quality indexes of sugarcane juice plays a vital role in the process of cultivation as well as production management. The application of 100% RDF through inorganic fertilizers alone reduced the quality of juice in terms of brix, sucrose and purity percent in late planted sugarcane variety CoS-767 as compared to control, whereas, the combination of both organic and inorganic fertilizers improved the quality of sugarcane over 100% NPK (Gangwar *et al.*, 2003)

After evaluating the long term effect of different levels of nitrogen applied either alone or in combination with organic manures on quality parameters of sugarcane at Sugarcane Research Institute, Bihar, India, Umesh *et al.* (2013) reported significant variation in content of commercial cane sugar (%) as well as pol (%). But other cane juice quality parameters *viz.*, brix, sucrose and purity coefficient did not differ significantly due to various treatments. Besides this, they also reported that integrated application of 100% RDF along with biogas slurry @ 20 t ha⁻¹ enhanced significantly the juice quality parameters like CCS (13.0 %), pol (18.1%) and sugar yield (9.1 t ha⁻¹) over 100% RDF (12.0%, 16.8% and 6.8 t ha⁻¹, respectively). Prasada *et al.* (1998) also reported that application of nitrogen in the form of organic manures and inorganic fertilizers tended to improve sugar recoveries. In another experiment, Kumar *et al.* (2019) reported that application of 100% RDF along with FYM @ 10 t ha⁻¹ and biofertilizers significantly improved the sugar yield (11.1 t ha⁻¹) than 100% recommended dose of NPK (9.5 t ha⁻¹). Similarly, Tyagi *et al.* (2012) also reported 26.5% more CCS yield with the application of 100% NPK + 25% N (FYM) + biofertilizers (*Azotobacter* +PSB) as compared to 100% NPK.

Commercial cane sugar (CCS) which is a function of cane yield and sucrose content exhibited similar trend of cane yield (Singh *et al.*, 2007; Thakur *et al.*, 2012). Kumar and Chand (2013) also reported significant increase in CCS% in both plant and ratoon crop of sugarcane due to integration of either FYM @ 12.5 t ha⁻¹ or *in situ* green manuring of *Sesbania aculeata* along with NPK as compared to NPK alone. They also reported significant improvement in sugar yield under said treatment combination. According to Lakshmi *et al.* (2011) the juice quality parameters such as sucrose, CCS and purity (%) remained unaffected due to different sources of manures. Kumar and Gaddanakeri (2015) also reported insignificant difference in juice quality

parameters like brix, pol and purity (%) due to different nutrient management practices. Similar results were also reported by Sridevi *et al.* (2016).

2.3 Effect of integrated nutrient management on soil health and nutrient status

The basic concept underlying the integrated nutrient management system nevertheless is the maintenance and possible improvement of soil fertility for sustained crop productivity (Yadav, 2000). Soomro *et al.* (2013) reported 25% saving of inorganic fertilizers due to application of FYM or pressmud @ 20 t ha⁻¹.

Balanced use of organic, inorganic and biofertilizers is very essential to maintain a good physical and chemical environment in soil. It also serves as an energy source for the soil microbial biomass and sustained the sugar productivity. Integrated nutrient supply has proved superior to the use of its components separately (Singh and Yadav, 1992). Tolanur and Badanur (2003) stated irrespective of nutrient sources, the effect of organic manures in conjoint with inorganic fertilizers was found to be superior over the inorganic treatment alone.

Kumar *et al.* (2015) also reported that application of biofertilizers along with 75% RDF recorded significantly higher microbial population such as fungi, bacteria, *actinomycetes*, PSB and *Azotobacter* than NPK without biofertilizers and thus able to compensate the application of 25% recommended dose of nitrogen and phosphorus.

Combined application of organic manures along with inorganic fertilizers was also reported to increase the soil organic carbon content due to addition of organic matter through manures as compared to chemical fertilizers alone. The inclusion of organic manures such as FYM, press mud, press mud cake, green manure along with recommended dose of NPK increased the soil organic carbon (OC %) from 0.39 up to 0.52% in first year plant crop and 0.44 up to 0.48% in subsequent ratoon crop (Kumar and Chand, 2013). This corroborated the findings of Singh *et al.* (2001). The application of FYM and green manure was also found to increase the organic matter in soil (Bokhtiar *et al.*, 2002). Kumar *et al.* (1999) conducted an experiment at Regional Research Station, Karnal, during 1996-97 for two sugarcane plant crops in sequence and result revealed that the application of FYM, press mud and green manure with *dhaincha* increased the organic carbon in soil, whereas, the same was decreased when no fertilizers were applied. The increase in organic carbon content in soil with the application of FYM, pressmud and green manure were also reported by Rabindra *et al.*

(1985) and Yaduvanshi and Yadav (1992). Lakshmi *et al.* (2011) also reported significantly higher organic carbon of 0.54% in plant crop and 0.55% in ratoon crop under the treatment receiving FYM @ 25 t ha⁻¹ + RDF as compared to RDF alone (0.49 and 0.49%) under plant-ratoon system. They stated that addition of huge quantities of manure *i.e.* @ 25 t ha⁻¹ might be responsible for improvement in soil physical and biological environment.

The integrated use of organic manures and inorganic fertilizers not only sustain soil and crop productivity but also protects soil health and prevents emergence of multiple nutrient deficiencies in soil system (Umesh *et al.*, 2013). Apart from increasing the cane yield, the combined application of FYM or compost @ 10 t ha⁻¹ + soil test-based RDF + biofertilizers (*Azotobacter* + PSB) @ 12.5 kg ha⁻¹ each greatly increased the amount of soil available nutrients such as P₂O₅ (10.93 kg ha⁻¹), K₂O (165.33 kg ha⁻¹) as compared to inorganic fertilizer alone (10.00 and 140.67 kg ha⁻¹, respectively) (Yadav *et al.*, 2018). In another experiment, Kumar and Verma (2002) reported that application of organic manure along with N, NP or NPK increased the availability of P and K in sugarcane grown field as compared to sole application of inorganic fertilizers. On the other hand, the available N and K₂O was not significantly affected due to application of different organic manures *viz.*, FYM, pressmud, *Azotobacter* and vermicompost along with inorganic fertilizers @ 100, 75 and 50% RDF on sugarcane *var.* Co- 8338. However, available P₂O₅ was significantly affected after the harvest of both plant and ratoon sugarcane (Trivedi *et al.*, 1997). The treatment receiving 100% RDF + FYM @ 20 t ha⁻¹ significantly showed highest value of available P₂O₅ (45.03 kg ha⁻¹ for plant and 56.63 kg ha⁻¹ for ratoon).

The soil available N that played a major role in growth and development of sugarcane decreased with advancement of crop growth (Kumar *et al.*, 2017). But, the integrated application of FYM, seasoned press mud and fertilizers had marked influence on soil available N (Venkata and Ravichandran, 2012). The application of 25% less inorganic fertilizers to the recommended level of chemical fertilizers along with press mud or FYM could be used to prevent nutrient depletion and maintain productivity as well (Bokhtiar *et al.*, 2005). Bokhtiar and Sakurai (2007) also reported that application of FYM or pressmud @ 15 t ha⁻¹ along with chemical fertilizers of N₁₇₈P₅₃K₅₄S₂₆Zn_{2.6} kg ha⁻¹ increased the soil available nutrients (N, P and S) and microbial count as compared to 100% RDF alone. Thus, reported the saving of 25% inorganic fertilizers due to addition of organic sources of nutrients such as FYM or pressmud. Gana and

Busari (2006) from Nigeria reported that FYM contributed highest amount of N (51 to 53.1 kg N ha⁻¹) to soil, thus helped in saving of inorganic fertilizers. The application of biofertilizers particularly phosphate solubilizing bacteria (PSB) was found to be effective when applied along with lower levels of phosphorous *i.e.* 60 kg P₂O₅ ha⁻¹ (Bangar and Sharma, 1997). The PSB might have increased the solubility of insoluble phosphate that facilitated better availability of soil phosphorous (Kapoor *et al.*, 1989). On the other hand, Yadav and Prasad (1992) reported that integrated application of both organic and inorganic fertilizers did not influence the soil organic carbon as well as available N, P, K after harvest of sugarcane crop.

The integrated nutrient management practices did not show any significant difference in soil pH and EC (Banerjee *et al.*, 2018). However, the addition of organic manures like FYM, vermicompost and pressmud cake decreased the soil pH from the initial value while, the application of chemical fertilizers slightly increased the soil pH due to accumulation of some salts (Lakshmi *et al.*, 2011).

2.4 Effect of integrated nutrient management on nutrient content and uptake by plants

Application of inorganic fertilizers coupled with FYM and biofertilizers significantly influenced the plant nutrient content at different growth stages of sugarcane. The N, P, K and S content were comparatively higher at tillering stage than the grand growth as well as subsequent growth stages (Banerjee *et al.*, 2018). Application of organic manures in combination with chemical fertilizers have been reported to increase the absorption of N, P and K in sugarcane leaf tissue in both plant and ratoon crop as compared to chemical fertilizer alone (Bokhtiar and Sakurai, 2005). In another experiment, Bokhtiar *et al.* (2015) reported that integrated nutrient management significantly influenced the nutrient content of sugarcane leaves at 150 DAP and among the treatments, the integration of 75 % RDF + pressmud enriched by *Trichoderma viride* @ 7.5 t ha⁻¹ recorded significantly higher N (1.54%) content that was at par with RDF + pressmud enriched by *Trichoderma viride* @ 7.5 t ha⁻¹ (1.47%), but found to be superior over 100% RDF (1.32%). But in case of P and K content, the application of RDF + pressmud enriched by *Trichoderma viride* @ 7.5 t ha⁻¹ recorded significantly higher values (0.13 and 1.24%, respectively) that was found to be at par with RDF (0.13 and 1.18%, respectively).

Keshavaiah *et al.* (2012) also reported significantly higher N (463.05 kg ha⁻¹) and P (34.26 kg ha⁻¹) uptake during harvesting and higher K uptake (239.34 kg ha⁻¹) at 6 months stage under the combined application of pressmud (75 kg N equivalent ha⁻¹) + biofertilizers (50 kg N equivalent ha⁻¹) along with chemical fertilizer (125 kg N, 50 kg P and 62.5 kg K₂O ha⁻¹) as compared to chemical fertilizers alone and treatments comprised of different organic nutrients. This indicates that neither organic nor inorganic sources alone could meet the nutrient requirement of sugarcane crop. On other hand More *et al.* (2007) reported significantly higher N uptake under 100% RD of nitrogen as compared to integration with sub optimal dose.

However, greater availability of N through sunhemp, biofertilizers and inorganic nutrients increased the N uptake by sugarcane (Manimaran and Kalyanasundaram, 2006). It was also reported that application of pressmud as organic source of nutrient recorded the highest N uptake by plant (227.7 kg ha⁻¹) as compared to any other organic source (Singh *et al.*, 2007). Similarly, the application of vermicompost @ 2.5 t ha⁻¹ along with RDF recorded significantly higher N uptake (301 and 301 kg ha⁻¹) which was found to be at par with application of FYM along with RDF (298 and 301 kg ha⁻¹), but superior to RDF alone (288 and 291 kg ha⁻¹) under plant-ratoon system (Lakshmi *et al.*, 2011). This might be due to improved physical condition of soil with better N availability which led to maximum uptake in these treatments (Singh *et al.*, 1995). However, irrespective of manure sources, combined application of inorganic and organic sources resulted in higher NPK uptake than inorganic source alone (Lakshmi *et al.*, 2011).

Application of K along with vermicompost and *Gluonacetobactor diazotrophics* recorded significantly higher K uptake (651.6 kg ha⁻¹) in ratoon crop as compared to sole K (Singh *et al.*, 2007). The sugarcane crop supplemented with 75% RDF (169-84-126) along with 20 t ha⁻¹ of pressmud recorded significantly higher concentration of N (1.35%), P (0.37%) and K (1.59%) in addition to higher uptake of N (150.14 kg ha⁻¹), P (40.94 kg ha⁻¹) and K (168.95 kg ha⁻¹) as compared to 100% RDF (Soomro *et al.*, 2012).

2.6 Effect of integrated nutrient management on economics of sugarcane

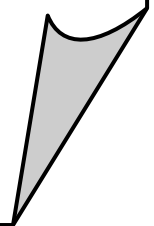
The higher B-C ratio of 6.36 was obtained when pressmud @ 20 t ha⁻¹ was applied along with three-fourth of the recommended dose of inorganic NPK fertilizers as compared to application of FYM @ 20 t ha⁻¹ along with three-fourth of the

recommended dose of inorganic NPK fertilizers (5.48). While, maximum net return of ₹ 1,79,760 was obtained with the application of FYM @ 20 t ha⁻¹ along with the application of three-fourth of the recommended inorganic NPK fertilizer (Soomro *et al.*, 2013). The integrated application of FYM @ 10 t ha⁻¹, bio fertilizer (*Acetobacter* + PSB) along with inorganic fertilizer (NPK) on soil test basis recorded the highest net return (₹ 298938 ha⁻¹) and B-C ratio (3.50) over other integrated nutrient management practices as well as sole application of inorganic fertilizer (Patel and Chaudhari, 2018). Similar finding was also reported by Yadav *et al.* (2018).

2.7 Crop establishment techniques and integrated nutrient management on growth and yield of sugarcane

Sugeerthi *et al.* (2018) conducted an experiment at Sugarcane Research Station, Cuddalore during 2017-18 to select an appropriate planting material of sugarcane seed crop and to ascertain the effective integrated nutrient management package to enhance the productivity of the same. Among the planting techniques, planting of bud chip seedlings recorded higher establishment percentage (87.01), plant height (229.46 cm), tiller population (113.01 '000 ha⁻¹), dry matter production (85.87 t ha⁻¹), single cane weight (1.80 kg cane⁻¹), seed cane yield (98.32 t ha⁻¹), gross return (₹ 2,94,962 ha), net return (₹ 1,83,040) as well as B-C ratio (2.63). Among integrated nutrient management practices, application of 75% of recommended NPK + *Azophos* + *in situ* incorporation of sunnhemp + foliar spraying of sugarcane booster resulted in higher establishment percentage (78.20), plant height (217.06 cm), tiller population (105.45 '000 ha⁻¹), dry matter production (86.77 t ha⁻¹), single cane weight (1.59 kg cane⁻¹), seed cane yield (88.71 t ha⁻¹), gross return (₹ 2,66,138 ha⁻¹) net return (₹ 1,56,819) and B-C ratio (2.42).

Materials and Methods... ✎



CHAPTER III

MATERIALS AND METHODS

An experiment was conducted to study the “Performance of bud chip seedlings under integrated nutrient management in autumn planted sugarcane (*Saccharum officinarum* L.)”. The investigation was carried out for two consecutive years 2017-18 and 2018-19 at Sugarcane Research Station, Assam Agricultural University, Buralikson, Assam. The details of material used and methods adopted during the present investigation are described in this chapter.

3.1 Geographical location of the experimental site

The experiment was conducted consecutively for two years *i.e.* 2017-18 and 2018-19 at the experimental farm of Sugarcane Research Station situated at village Buralikson, Golaghat district which is 45 km away from the AAU Headquarter, Jorhat, Assam. The place is situated between 26.46°N latitude, 94.12°E longitude and having an altitude of about 86.6 M above the mean sea level. It is the only research station on sugarcane in the entire NE region and the soil and weather is suitable for sugarcane cultivation.

3.2 Climate and weather conditions

The agro-climatic conditions of experimental area of Sugarcane Research Station, Buralikson, Golaghat falls under Upper Brahmaputra Valley Zone of Assam typically characterized by sub-tropical humid with hot summer and cold winter. The average annual rainfall of the district is more than 2000 mm with uneven distribution of rainfall throughout the year. The monsoon rain starts from the month of June and continues up to the month of September - October with the pre monsoon showers from mid March to April. The intensity of rainfall decreases from mid of October and reaches minimum during December-January. Being an area under sub-tropical humid region, the relative humidity is very high during the monsoon with less relative humidity during the cold months. The mean monthly maximum temperature ranges between 34-37°C during summer, while, the minimum temperature range falls between 8-10°C during winter.

The meteorological data of the experimental plot recorded at the meteorological observatory of Sugarcane Research Station, Buralikson, Golaghat during the crop season of the experiment have been presented in Annexure I(a) and Annexure I(b) and illustrated diagrammatically in Fig. 3.1(a), 3.1(b), 3.1(c) and 3.1(d).

During both the years of experimentation, the crop received sufficient amount of rainfall throughout the growing period. The rainfall received during first year *i.e.* mid October, 2017 to 1st week of January, 2019 was comparatively less as compared to second year crop grown between mid October, 2018 to 1st week of January, 2020. Altogether, an amount of 1858.0 mm rainfall was received during 2017-18 with 94 of rainy days, while an amount of 2265.7 mm rainfall was received with 122 of rainy days during 2018-19 from planting to harvesting.

The weekly mean maximum temperature ranged from 22.5 to 35.0°C and 20.7 to 34.8°C from sowing to harvesting during 1st and 2nd year crop, respectively. The weekly mean minimum temperature ranged between 8.2 to 26.9°C during 2017-18 and 8.1 to 26.8°C during 2018-19.

The weekly average relative humidity during the morning hours ranged from 85 to 100 and 86 to 100% during growing period of 1st and 2nd year crop, respectively. While, the weekly average relative humidity during evening hours ranged from 53 to 83% during 2017-18 and 53 to 90% during 2018-19.

The maximum weekly bright sunshine hours of 8.4 hours day⁻¹ was recorded during 1st year and 8.2 hours day⁻¹ was recorded during the second year. While the minimum weekly bright sunshine was 1 hour day⁻¹ during 1st year and 0 hr day⁻¹ was received during 2nd year crop.

3.3 Cropping history and selection of site

A rectangular shaped medium upland area of length 78 metre and breadth 24 metre was selected for the experiment in the Sugarcane Research Station, Buralikson, Golaghat. The sites selected for 2017-18 and 2018-19 were adjacent to each other. In the experimental site sugarcane was grown year after year as monocrop. However, just to build up the organic matter the land remained fallow occasionally. In both the years of experimentation, the crop was grown during the autumn season after

harvesting of spring planted sugarcane and before conducting the experiment, the land was remained fallow in both the sites.

3.4 Initial analysis of soil physic-chemical and biological properties

For determining the physico-chemical properties of the experimental area, the representative soil samples were collected randomly from 0-30 cm during both the years. The collected composite samples were air dried and ground with a wooden roller and finally passed through 0.2 mm sieve. After thorough mixing, the soil samples were analyzed for both physical and chemical properties of soil. The results of soil analysis and methods used for determination are presented in Table 3.1.

From the Table 3.1, it can be summarized that soils of the experimental site in both the years *i.e.* 2017-18 and 2018-19, were clay loam in texture, acidic in nature (pH 5.46 and 5.48), medium in organic carbon (0.71 and 0.68%) and available K₂O (194.33 and 187.66 kg ha⁻¹) low in available N (231.42 and 226.77 kg ha⁻¹ kg ha⁻¹) and available P₂O₅ (19.28 and 18.64 kg ha⁻¹).

3.5 Variety

The sugarcane variety CoBln 9104 (Lohit) is an early as well as mid maturing variety specially recommended for Assam. The variety is known for its profuse tillering ability with very good yield (70-80 t ha⁻¹) as well as jaggery (gur) recovery (10-12%) and recommended for all six zones of Assam. The variety is moderately susceptible to top and plassey borer.

3.6 Experimental details

The experiment on sugarcane was carried out during autumn season for two consecutive years 2017-18 and 2018-19. The experiment was laid out in split plot design with three replications. The treatments were allocated randomly to each plot to avoid biasness. The experiment comprised of combination of fifteen treatments with three treatments under main plot and five treatments under sub plot. The details of treatments are presented below and layout of the experiment is presented in Fig. 3.2.

Table 3.1. Physico-chemical and microbiological properties of the experimental site

Soil property	Value		Textural	Method
	(2017-18)	(2018-19)	class/rating	employed
A. Mechanical composition				
i) Sand (%)	41.14	40.75	} clay loam in texture	International pipette method (Piper 1966)
ii) Silt (%)	25.60	25.41		
iii) Clay (%)	33.24	33.82		
B. Chemical properties				
i) Soil reaction (pH)	5.46	5.48	Acidic	Glass electrode method, (Jackson, 1973)
ii) Organic carbon (%)	0.71	0.68	Medium	Wet Digestion Method (Walkey and Black, 1934)
iii) Available N (kg/ha)	231.42	226.77	Low	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
iv) Available P ₂ O ₅ (kg/ha)	21.38	20.44	Low	Bray-I Method (Jackson, 1973)
v) Available K ₂ O (kg/ha)	187.64	184.32	Medium	Flame Photometer Method (Jackson, 1973)
C. Biological properties (Soil microbial properties)				
i) Bacteria	5.36	5.26		Serial dilution technique
ii) Fungi	4.48	4.37		

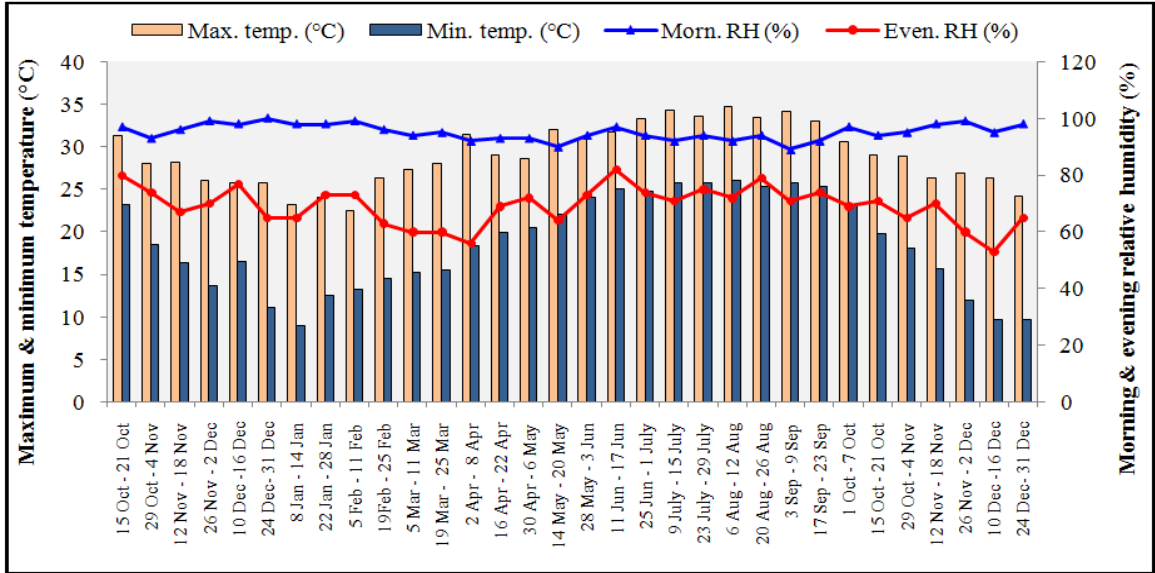


Fig. 3.1(a). Meteorological parameters during the crop growth period of sugarcane (2017-18)

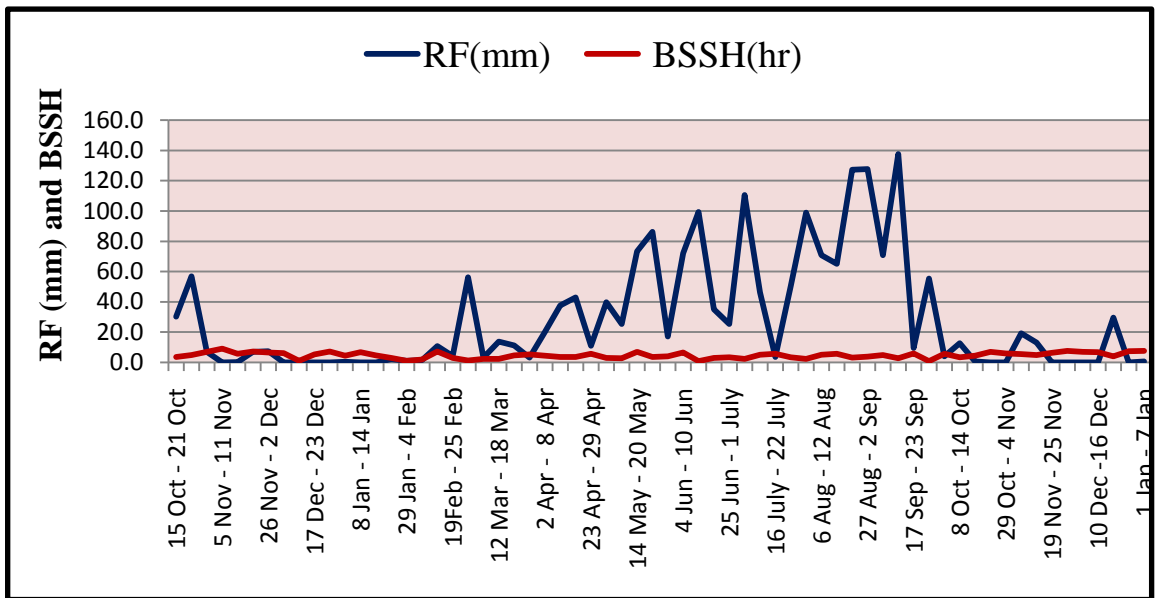


Fig. 3.1(b). Meteorological parameters during the crop growth period of sugarcane (2017-18)

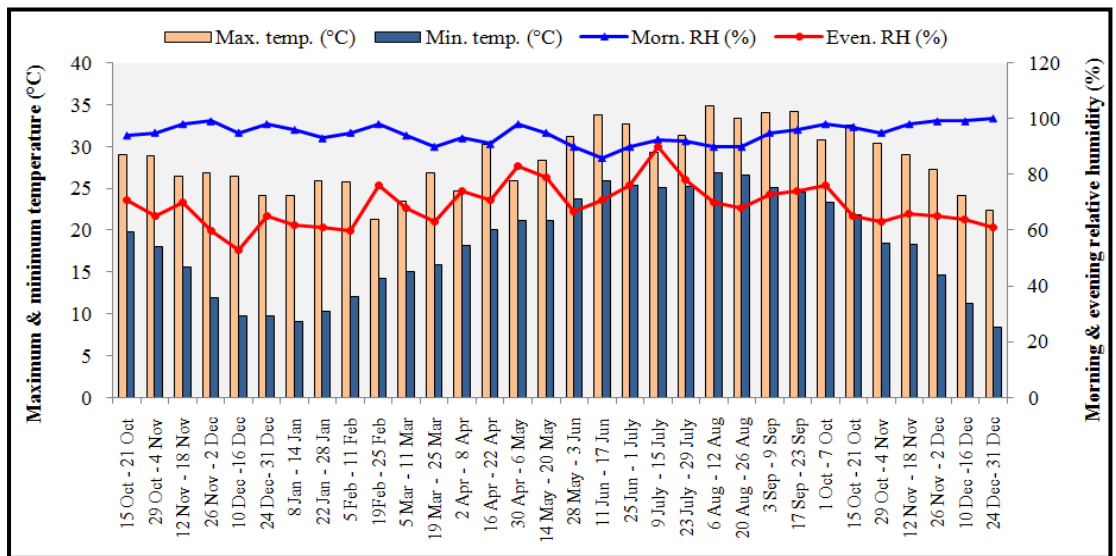


Fig. 3.1(c). Meteorological parameters during the crop growth period of sugarcane (2018-19)

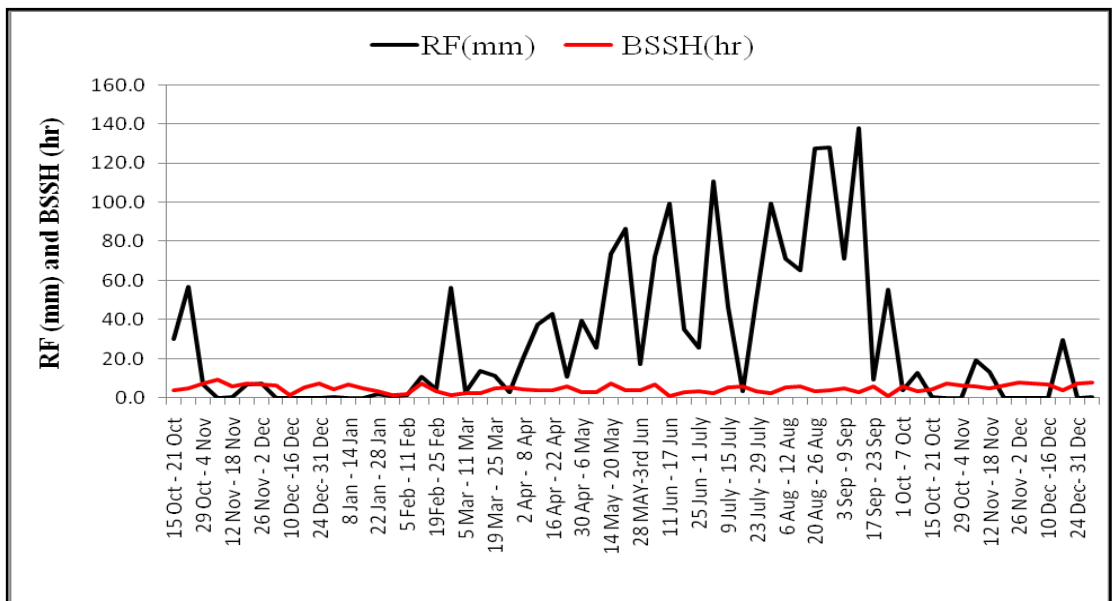


Fig. 3.1(d). Meteorological parameters during the crop growth period of sugarcane (2018-19)

3.6.1 Design and layout

Design	: Split Plot Design
Treatment Combinations	: 15
Replications	: 3
Total no. of plots	: $15 \times 3 = 45$
Gross plot size	: $7.2 \text{ m} \times 3.6 \text{ m} = 25.92 \text{ m}^2$
Gross area	: 1872 m^2
Net area	: 1166 m^2
Variety	: CoBln 9104 (Lohit)
Row spacing	: As per treatments

3.6.2 Treatment details

Main plot (Crop establishment techniques)

M₁: Conventional method of planting

M₂: Planting of bud chip seedling at a spacing of 90 cm x 60 cm

M₃: Planting of bud chip seedling at a spacing of 120 cm x 60 cm

Sub plot (Integrated nutrient management)

F₁: Recommended dose of fertilizer (RDF): 135- 70- 60 N-P₂O₅-K₂O kg ha⁻¹

F₂: 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring (cowpea incorporation)
+ biofertilizers (*Azotobacter* + PSB) @ 10 kg ha⁻¹ each

F₃: 100% RDF + enriched compost @ 1t ha⁻¹ + green manuring (cowpea incorporation)

F₄: 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring
(cowpea incorporation) + biofertilizers (*Azotobacter* + PSB) @ 10 kg ha⁻¹ each

F₅: 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring
(cowpea incorporation)

3.6.3 Imposing of treatments in main field

In case of main plot there were three crop establishment techniques, out of these in M₂ and M₃, (as shown in treatment details), sugarcane bud chip seedling were

planted in two different planting geometry. For raising sugarcane bud chip seedlings, the bud chip along with a portion of cane were extracted and after that they were treated with fungicidal solution for 10 minutes and dried in shade for two hours. The treated bud chip portions were then planted in plastic cups using vermicompost as growing media. For quick germination of seedling regular watering was done to maintain the optimum moisture content and stopped the watering process just 3-4 days before transplanting into main field.

While in case of M_1 , conventional 3 budded planting methods was followed. In this crop establishment technique, canes were cut in such a way that each portion had at least 3 healthy buds and the three budded setts were planted directly in main field with furrows of 90 cm apart. Before planting the setts in main field they were treated with fungicidal solution to avoid any sett born diseases.

In case of sub plot, five treatments comprised of integrated nutrient management were randomly allocated. Out of these one was totally inorganic and rest four was combination of different organic, inorganic source of nutrients as well as biofertilizers. Regarding the application of inorganic fertilizers, one third of N and K_2O and full dose of P_2O_5 were applied as urea, MOP and SSP in furrows just one day before planting and they were thoroughly mixed with the soil. While, other two splits were applied during the time of first and second earthing up operation.

In case of organic source of fertilizer, the well decomposed farmyard manure (FYM) was locally collected from nearby areas of experimental site. While biofertilizers, both *Azotobacter* and phosphate solubilizing bacteria (PSB) as well as vermicompost and enriched compost were collected from department of soil science, Assam Agricultural University, Jorhat. All the organic sources like FYM, enriched compost, vermicompost were applied on dry weight basis as basal as per treatments. Bio-fertilizers were applied to soil @ 10 kg ha^{-1} each of *Azotobacter* and PSB by mixing with vermicompost as per treatments. In all the treatments excluding 100% RDF, cowpea was grown *in situ* as a green manuring crop in between rows of main crop and incorporated in soil at 65 days after planting. The nutrient content of all these organic sources were determined before applying in crop field (Table 3.2 and 3.3).

Table 3.2. Moisture and NPK content of organic inputs

Particulars	FYM		Vermicompost		Enriched compost	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Moisture (%)	35.34	34.72	46.84	45.88	33.48	33.46
N content (%)	0.58	0.54	1.87	1.85	1.63	1.66
P content (%)	0.23	0.22	1.16	1.13	0.73	0.72
K content (%)	0.51	0.48	1.44	1.44	1.11	1.06

Table 3.3. Nutrient composition and contribution from green manuring of cowpea

Year	Average Dry biomass yield (qha ⁻¹)	Nutrient content (%)			N (kg ha ⁻¹)	P (kg ha ⁻¹)	K (kg ha ⁻¹)
		N	P	K			
2017-18	22.06	1.65	0.56	1.11	36.40	12.36	24.48
2018-19	21.74	1.67	0.57	1.13	36.31	12.40	24.56

3.7 Agronomic practices followed for growing the autumn planted sugarcane

The schedules of field operations carried out during the experimentation are given in Annexure 2.

3.7.1 Preparation of land and layout

The first land preparation was done one month before planting of crop by giving one deep ploughing with tractor drawn disc plough followed by two cross harrowing by disc harrow. The land was made free from all unnecessary weed biomass, stubbles, debris and undecomposed plant materials. Then the field was leveled and plots were laid according to the layout plan given in Fig. 3.2. After that treatment combinations were applied randomly as per statistical design.

3.7.2 Irrigation

In the main field, irrigation was given in furrows just after transplanting of the seedling for easy and quick establishment of seedlings and for proper germination of setts. Also supplementary irrigation was given during the dry period mainly in December for proper growth of the crop.

3.7.3 Gap filling

To maintain the proper plant population, gap filling was done in all the crop establishment techniques. In case of bud chip seedlings the dead seedlings were replaced by fresh seedlings within ten days after transplanting and in case of conventional method the pre germinated setts planted in adjacent area of the experimental field planted in same date were utilized for gap filling.

3.7.4 Earthing-up

Earthing-up of sugarcane were generally done to support the plant and to avoid lodging of the cane stalk. In all the treatments two times earthing up were done, one partial earthing up at 90 days after planting and full earthing up at 150 days of planting . The initial growth of stalks were very slow because of low temperature due to which the full earthing up was done at bit late than the spring planted crop.

3.7.5 Pest and disease management

All the recommended package and practices developed by Assam Agricultural University were followed for control of pest and diseases of sugarcane to find out the best effect of treatments. Prior to planting of setts as well as bud chip it was treated with 0.1% Carbendazim for 10 mins. The crop was infested by early shoot borer during both the years and to control it Chloropyriphos 20 EC of 0.02% was applied at the whorl. To control the problem from red ants as well as termites Malathion 5% dust was applied in furrows before planting.

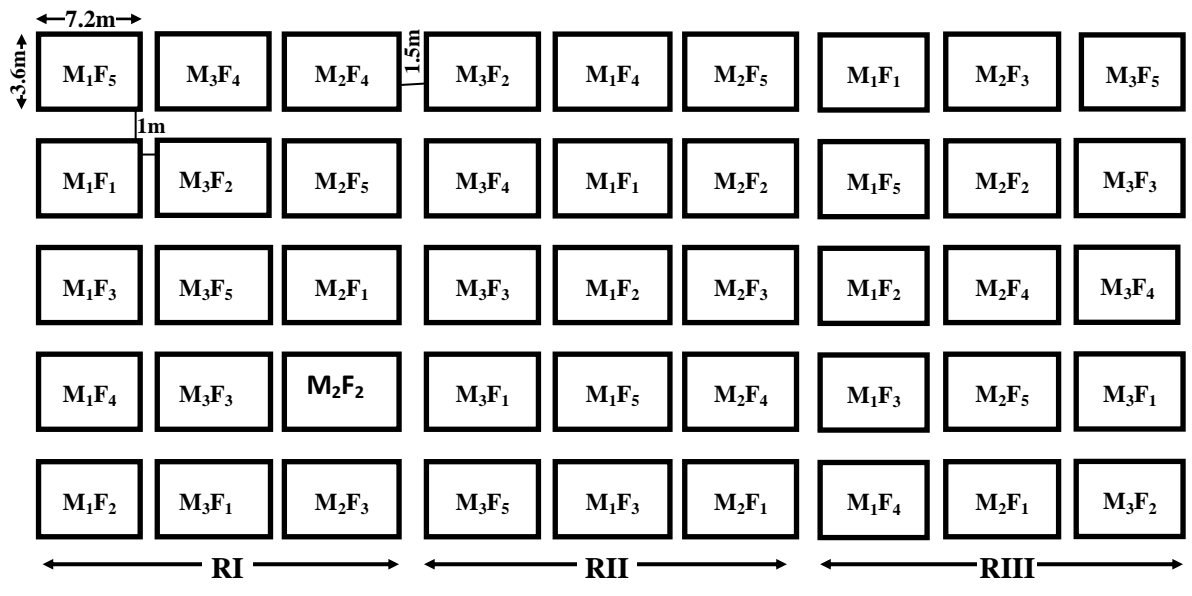
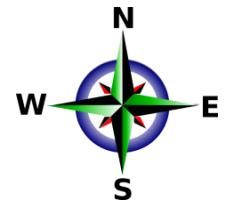


Fig. 3.2. Layout of the experiment



3.7.6 Time of harvesting

Maturity of cane stalk was determined by measuring the brix (%) in cane with the help of hand refractometer following the standard field procedure recommended by Sugarcane Research Station, Assam Agricultural University.

3.7.7 Harvesting of canes

The millable canes of the net plot area (excluding the border rows) were harvested with the help of sickles by cutting at ground level. To determine the stripped cane yield all the green top and dry leaves from the stalks were separated from the cane. The bundles of millable cane were weighed and computed the yield on tones ha^{-1} basis. Similarly the weight of green and dry leaves were also weighed separately and then converted into tones ha^{-1} .

3.8 Biometric observations recorded

Starting from planting/transplanting up to final harvesting various measurements on growth, yield attributing and qualitative characteristics were made in order to assess the treatment effect. The following parameters were taken adopting proper procedure. Ten representative plants/mother plants from each plot were randomly selected and labeled for subsequent observations for some of the characters.

3.8.1 Growth parameters

3.8.1.1 Number of total shoots population ('000 ha^{-1})

The total number of shoot population from the net plot area were calculated at 30 days interval starting from 90 to 240 days after planting and converted into ha. The shoot population figure was expressed in '000 ha^{-1} .

3.8.1.2 Number of shoots per plant⁻¹

For determining the average number of shoots plant^{-1} at periodical interval, the total number of tillers of selected plant was counted at a regular interval and their average was taken in case of M_2 and M_3 technique, while in case of conventional method (M_1), total shoot population from two rows were calculated and it was divided by mother shoot counted at the time of germination period.

3.8.1.3 Number of physiologically active leaves shoot⁻¹

It was recorded by randomly selecting five shoots or tillers in each plot through a random selection and then number of green leaves on each shoot were counted and averaged.

3.8.1.4 Plant height (cm)

The height of fifteen randomly selected plants was measured in centimeters from the base of the plant to the collar region at an interval of 60 days. The mean height was expressed in centimeter.

3.8.1.5 Leaf area shoot⁻¹

Functional leaves *i.e.* green leaves were counted on the primary tillers of plant sampled by uprooting the plants, and then measuring the total leaf area by measuring the length and breath. Leaf area was measured manually by using the formula described by Hunt (1978).

$$\text{Leaf area} = \text{Leaf length} \times \text{leaf width} \times \text{CF} (0.75).$$

The leaf area of randomly selected three (3) primary shoots from three (3) mother plant was calculated and their average was taken.

3.8.1.6 Leaf area index (LAI)

Leaf area of ten randomly selected stalks from each treatment plot at periodical intervals was measured as mentioned earlier. After that leaf area index (LAI) was determined by using the formula given below:

$$\text{LAI} = \frac{\text{Leaf area (m}^2\text{)}}{\text{Ground area (m}^2\text{)}}$$

3.8.1.7 Leaf area duration (LAD) (days)

Leaf area duration of a crop is measure of its ability to produce leaf area on unit area of land throughout its life (Power *et al.*, 1967). LAD is calculated by the formula:

$$\text{LAD (days)} = \frac{L_i + L_{(i+1)}}{2} \times (T_2 - T_1)$$

Where,

LAD = Mean leaf area duration (days)

L_i = LAI at i^{th} stage

$L_{(i+1)}$ = LAI at $(i+1)^{\text{th}}$ stage

$(T_2 - T_1)$ = Time interval between i^{th} and $(i+1)^{\text{th}}$ stage in days

3.8.1.8 Crop Growth Rate (CGR) ($\text{g m}^{-2} \text{day}^{-1}$)

It represents dry weight gained by a unit area of crop in a given time. Crop growth rate of three randomly selected stalks from each treatment plot at 60 days interval was measured. To determine the CGR, at first the selected plants were sun dried and kept in oven at 70°C for 48 hours. CGR was determined by using the following formula given by Watson (1952) and expressed as $\text{g m}^{-2} \text{day}^{-1}$.

$$\text{CGR} = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{P}$$

Where,

W_1 and W_2 are shoot dry weight m^{-2} at time t_1 and t_2 , respectively.

t_1 and t_2 are time interval between two harvests

P is land area over which dry matter was recorded

3.8.1.9 Relative Growth Rate (RGR) ($\text{g g}^{-1} \text{day}^{-1}$)

Relative growth rate (RGR) is defined as the rate of dry matter production per unit time. It was calculated by formula given below (Radford, 1967) and expressed as $\text{mg g}^{-1} \text{day}^{-1}$.

$$\text{RGR} = \frac{(\text{Log}_e W_2 - \text{Log}_e W_1)}{t_2 - t_1}$$

Where,

RGR = Mean relative growth rate ($\text{g g}^{-1} \text{day}^{-1}$)

W_1 and W_2 = Dry weight of plant at time t_1 and t_2 , respectively

Log_e = Logarithm to the base 'e'

3.8.1.10 N related parameters

3.8.1.10.1 Total chlorophyll content (mg g^{-1})

Chlorophyll content at various growth stages were estimated with the help of Acetone method (Arnon, 1949). A fresh leaf sample of 1g weight was chopped into fine pieces and homogenized with pre cooled mortar and pestles using 80 percent (V/V) acetone and a pinch of calcium carbonate. The extract was then centrifuged at 3000 rpm for 15 minutes made up to volume of with 80 percent (V/V) acetone. The optical density of clear solution was measured at 645 nm and 663 nm, against an 80%

acetone blank in UV-VIS spectrophotometer. The total chlorophyll content was determined using the equation given below

$$\text{Total chlorophyll } (\mu\text{g}^{-1} \text{ ml}^{-1}): (20.2 \times \text{O.D at } 645 \text{ nm}) + (8.02 \times \text{O.D at } 663 \text{ nm})$$

The chlorophyll content was expressed as mg g^{-1} fresh weight of the leaf.

3.8.1.10.2 Green seeker NDVI (Normalized Difference Vegetation Index)

The green seeker value indicates plant health condition and its value ranged between 0-0.99. The NDVI value was recorded with the help of digital green seeker at 330 DAP. The value was taken randomly in ten number of standing plant and their average was taken.

3.8.1.10.3 Crop canopy temperature ($^{\circ}\text{C}$)

The crop canopy temperature was measured with the help on infrared thermometer during 330 DAP. The crop canopy temperature of ten randomly selected standing crops was measured and their average was taken.

3.8.1.11 Root length (cm) and root dry matter plant (g)

For calculation of root length and root dry weight, three randomly selected whole plants were uprooted carefully from boarder rows. Before uprooting the plants, watering was done to avoid damage to the roots. The roots were separated out from the above ground portion and washed to remove the excess mud. The length of root was measured with the help of scale and average was taken. For determining the dry weight of root oven drying was done.

3.8.1.12 Dry weight of above ground biomass shoot⁻¹

For calculation of dry weight of above ground biomass shoot⁻¹ (the dry weight of stems, leaves and the total plant), five of randomly selected shoots from boarder rows were collected from each treatment. Thereafter, the leaves and stem of the sample were separated and oven dried at 80°C . The weight was taken separately and finally their average was calculated.

3.8.2 Yield attributing characters

3.8.2.1 Millable cane length (cm)

The height of ten already randomly selected millable canes in each treatment was recorded and their average was taken. The height of millable cane was

determined from the ground level to the last internode and mean height of the millable cane was expressed in cm.

3.8.2.2 Cane diameter (cm)

For determining the diameter of the cane, ten numbers of millable canes were randomly selected already from each treatment and diameter of the cane in bottom, middle and top portion was measured with the help Vernier Caliper and their average was taken.

3.8.2.3 Number of millable cane ('000 ha⁻¹)

Number of millable cane per net area was recorded at the time of harvest and expressed in '000 ha⁻¹. The boarder rows of each plot were not included during data collection.

3.8.2.4 Average weight of millable cane (kg cane⁻¹)

The weight of ten millable canes was taken with the help of spring balance and averaged to get the weight of individual millable cane in kilograms.

3.8.2.5 Length of internode (cm)

For determining the length of internode, the same ten millable canes were taken from each treatment and the length of internode in bottom, middle, top portion of the cane was measured with the help of measuring tape.

3.8.2.6 Number of internodes millable cane⁻¹

At time of harvest, internodes of already randomly selected ten millable canes from each treatment were counted and their average was taken.

3.8.3 Yield and harvest index

3.8.3.1 Cane yield (t ha⁻¹)

For determining the cane yield, the net plot excluding the boarder rows was harvested at maturity. The dry leaves and top tender portion was removed from the millable cane and weight of stripped canes were taken and expressed in t ha⁻¹.

3.8.3.2 Green top yield (t ha⁻¹)

The green tops of all the canes in the net plot were removed and its yield per net plot was recorded and expressed as t ha⁻¹.

3.8.3.3 Trash yield (t ha⁻¹)

The trash (dry leaves) of all the canes in the net plot was removed and its yield per net plot was recorded and expressed as t ha⁻¹.

3.8.3.4 Biological yield (t ha⁻¹)

It is the sum of cane yield, green top as well as trash yield of sugarcane from net plot area, which is also expressed in t ha⁻¹.

3.8.3.5 Harvest index (%)

It is the ratio of economic yield (stripped cane yield) to the biological yield which was worked out by following formula (Donald and Hamblin, 1976) and expressed in per cent.

$$\text{HI (\%)} = \frac{\text{Stripped cane yield (t ha}^{-1}\text{)}}{\text{Biological yield (t ha}^{-1}\text{)}} \times 100$$

3.8.4 Qualitative studies

3.8.4.1 Field Brix (%)

Field brix is measured in the bottom, middle and top portion of the standing cane with the help of hand refractometer.

3.8.4.2 Juice extraction (%)

The fresh cane weight of two millable cane was taken and after that the juice was extracted from the cane with the help of cane crusher machine. The juice was collected and weight of juice was recorded.

The per cent juice extraction was calculated by using the following formula:

$$\text{Juice extraction \%} = \frac{\text{Weight of the juice extracted}}{\text{Weight of the cane}} \times 100$$

3.8.4.3 Sucrose (%)

About 100 ml of juice was taken in a 250 ml of conical flask and 2 g dry lead acetate was added to it. Then the flask was shaken for five minutes followed by

vigorous stirring and mixture was filtered through Whatman No. 42 filter paper. The clear filtrate was taken in a 20 cm polarimeter tube to record pol reading using Horne's Dry Lead Acetate method as described by Spencer and Meade (1955). Schmitz's table was used to calculate per cent sucrose using corrected brix and pol readings.

3.8.4.5 Commercial cane sugar (CCS %)

Percent available sugar in cane was calculated by using the following formula:

$$\text{Available sugar in cane (\%)} = [S - (B - S) \times 0.4] \times 0.73$$

Where,

S = Percent sucrose in juice

B = Corrected brix of juice

3.8.4.6 Purity (%)

The purity of cane juice was judged by calculating purity coefficient (%) by using following formula:

$$\text{Purity (\%)} = \frac{\text{Pol percent in juice}}{\text{Brix corrected}} \times 100$$

3.8.4.7 Commercial cane sugar (t ha⁻¹)

The commercial cane sugar (C.C.S.) in tones per hectare was calculated by using the following formula:

$$\frac{\text{Available sugar (\%)} \text{ in cane} \times \text{cane yield (t ha}^{-1}\text{)}}{100}$$

3.8.5 Plant analysis

The plant material *i.e.* green tops, cane stalk and trash obtained after the harvest of the crop were collected from each plot, tagged and well dried in sun light. Then it was again kept in hot oven at 70°C for 48 hours for complete drying to obtain constant weight. The samples used to determine the nutrient content and uptake of nitrogen, phosphorus and potassium by cane stalk, green top and trash were ground separately in to fine powder.

3.8.5.1 Nitrogen content (%)

The oven dried sample of cane stalk, green tops and trash were used to analyze their nitrogen content using Micro-Kjeldahl's method (Jackson, 1973).

3.8.5.2 Phosphorus content (%)

The oven dried sample of cane stalk, green tops and trash were used to analyze their phosphorus content using Vanado-molybdo-phosphoric yellow colour method (Jackson, 1973).

3.8.5.3 Potassium content (%)

The oven dried sample of cane stalk, green tops and trash were used to analyze their potassium content using Flame photometer method (Jackson, 1973).

3.8.5.4 Nutrient uptake (kg ha⁻¹)

The uptake of nutrient was calculated separately for cane stalk, green tops and trash and summed together to get the total uptake. To work out the nutrient accumulation in each part their dry matter yield was multiplied by their respective nutrient content as follows:

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} : \text{Dry matter yield (kg ha}^{-1}\text{)} \times \frac{\text{Nutrient content (\%)}}{100}$$

3.9 Soil analysis

3.9.1 Soil pH

The pH of soil from each plot was determined after harvesting of sugarcane in each year as per the method given in Table 3.1.

3.9.2 Available N, P₂O₅ and K₂O (kg/ha)

Soil samples collected from each plot after harvesting of crop each year were air dried, ground and sieved through 2 mm diameter sieve and were used for estimation of available nitrogen, phosphorus and potassium as per the method given in Table 3.1.

3.9.3 Microbial population (10^4 *cfu g⁻¹ soil)

The classical serial dilution technique was used for isolation of total bacterial and fungal population from soil by spread plate technique on appropriate media. Initially the soil sample of 1 g each was suspended in 9 ml water blank followed by serial dilution up to 10^{-4} and 10^{-6} . Nutrient agar was used for counting total bacterial population, while Rose Bengal media was used for enumeration of fungal population. Antibiotic *Streptomycillin* sulphate was added in the melted media (45°C) before plating. Aliquots of 100 µl of 10^{-4} and 10^{-6} dilution were spread over the solidified media in triplicates. Nutrient agar and Rose Bengal media plates were incubated at $30\pm 1^\circ\text{C}$ for 2 days. The microbial number was estimated as log colony forming unit (cfu g⁻¹ soil) on dry weight basis.

3.10 Economic studies

3.10.1 Cost of cultivation (₹ha⁻¹)

It was calculated on per hectare basis for each treatment by taking into account the prevailing cost of inputs, labor and operational cost. The details are presented in Annexure III (a), III (b), III (c) IV (a) and IV (b).

3.10.2 Gross and net return (₹ ha⁻¹)

Gross return was the value of the economic yield calculated at the prevailing market price. Net return was calculated by subtracting the cost of cultivation from the gross return on per hectare basis.

$$\text{Net return} = \text{Gross return} - \text{Cost of cultivation}$$

3.10.3 Benefit - Cost (B- C) ratio

The benefit - cost ratio was computed by dividing the net return by the total cost of cultivation.

3.11 Statistical analysis

All the data pertaining to the present investigation wherever needed were statistically analyzed adopting the procedure of analysis of variance (ANOVA) in split-plot design described by Sarma (2016). The significance of the variance due to the treatment effect was determined by calculating the respective 'F' values. Critical differences (CD) at 5 per cent probability level were calculated only when the 'F' value

been found out to be significant, otherwise S.Em (\pm) was mentioned. The standard errors and t-value was calculated by using the following expressions:

Mean compared	Standard Error (SEm)	t-value
T mean	$\sqrt{\frac{\text{EMS (a)}}{rw}}$	At Error (a) degree of freedom (t_a)
W mean	$\sqrt{\frac{\text{EMS (b)}}{rt}}$	At Error (b) degree of freedom (t_b)
W mean at same level of T	$\sqrt{\frac{\text{EMS (b)}}{r}}$	At Error (b) degree of freedom (t_b)
T mean at same level or different level of W	$\sqrt{\frac{\text{EMS(a)} + (w - 1)\text{EMS(b)}}{rw}}$	$\sqrt{\frac{t_a \text{EMS(a)} + t_b [(w - 1)\text{EMS(b)}]}{\text{EMS(a)} + (w - 1)\text{EMS(b)}}$

Where, EMS(a) = Error mean square for tillage levels

EMS(b) = Error mean square for weed management levels

r = Number of replications

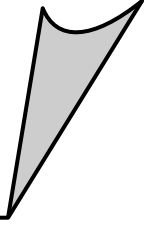
t = Levels of tillage practices

w = Levels of weed management

The critical difference (CD) was calculated to find out the significance of mean difference amongst treatment by following formula :

$$\text{CD}(0.05) = \sqrt{2} \text{SEm } t_{0.05} \text{ - value}$$

Results and Discussion... 



CHAPTER IV

RESULTS AND DISCUSSION

A study on “Performance of bud chip seedlings under integrated nutrient management in autumn planted sugarcane (*Saccharum officinarum* L.)” was carried out for two consecutive years viz., 2017-18 and 2018-19 at the experimental field of Sugarcane Research Station, Assam Agricultural University, Buralikson. The biometric observations in terms of growth, yield attributes and yield as influenced by crop establishment techniques and integrated nutrient management practices were measured. The juice quality parameters, nutrient uptake by plants, post harvest nutrient status as well as the economics under different treatments were also determined. Thus, all the possible parameters were taken into consideration to fulfill the objectives of the experiments. Finally, the data in respect of all the parameters were analyzed by standard statistical method and analyses of variances are presented in appendices (I to XXIV).

Weather condition

The success of any crop depends upon the good weather condition and able to show its maximum potential under favorable condition along with proper crop husbandry. In the present investigation, the crop received a good amount of rainfall throughout the crop growing period during both the years of experimentation. However, variation in quantity and intensity of rainfall observed between the two years led to the variation in crop yield. The rainfall received during the whole crop growing period for the first crop that covered a period of almost 15 months starting from mid October, 2017 to 1st week of January, 2019 was comparatively lower as compared to the second crop that also covered the same period starting from mid October, 2018 to 1st week of January, 2020. Altogether, an amount of 1858.0 mm rainfall was received during 2017-18 with 94 numbers of rainy days, while an amount of 2265.7 mm rainfall was received with 122 numbers of rainy days during 2018-19 from planting to harvesting. The crop received good amount of rainfall during October, 2017 and 2018 which helped in proper establishment of crop during both the seasons. At the time of planting, the weekly maximum day temperature was 31.3 and 29.0°C, respectively, which was favorable for germination of crop during both the seasons. But, during December and January the

lowest temperature were received in case of both the crops resulting in slow growth during that particular period.

During early stage of crop growth up to 150 days after planting *i.e.* mid October to mid March, the first year crop received comparatively more amount of rainfall (202.3 mm with 12 rainy days) as compared to second crop which received an amount of 132.4 mm with only 10 rainy days. During this crop growing period, the mean weekly maximum temperature ranged from 22.6 to 31.2°C in 1st year crop, while it ranged from 21.3 to 30.7°C in 2nd year crop. Similarly, weekly average minimum temperature ranged from 8.9 to 23.2°C during 1st year crop, while, it ranged from 8.1 to 19.8°C during second year. The variation in rainfall and temperature during this particular crop growing period might be the reason for difference in growth parameters in early stage of crop growth in case of both the crop seasons. The prevalence of low temperature during December and January resulted in slow growth of the crop during both the seasons, however, during the second year, all the initial growth parameters including root growth was comparatively less because of drop of temperature along with very low rainfall.

The intensity of rainfall greatly increased from March onwards and lasted up to mid of September during 1st season crop, while, it continued up to last week of September during the second crop. During this period, 1035 mm of rainfall was received in first year crop against 1862 mm of rainfall during the second year. Likewise, the temperature also gradually increased from March onwards that helped in faster growth of crop along with the increasing intensity of rainfall. During this period, the weekly maximum temperature ranged from 28.7 to 35.0°C during 1st season crop, while, it ranged from 26.1 to 34.8°C during 2nd season crop. Similarly, the weekly average BSSH was 4.8 hrs in 1st season crop against 3.77 hrs during 2nd season crop. The high amount of rainfall during the grand growth of sugarcane in case of 2nd season crop along with less BSSH reduced the crop growth, while, the optimum rainfall along with high temperature and more BSSH encouraged the crop growth in case of 1st season crop.

The amount and intensity of rainfall started ceasing from October onwards and very low amount of rainfall was received during both November and December in 2017-18 and 2018-19. During October about 17.4 and 251 mm of rain was received for 1st year and 2nd year crop, respectively. Because of high amount of rainfall

received during this period in second year crop, the quality parameters were comparatively poor as compared to 1st season crop. But, during the month of November and December, the lowest amount of rainfall was received in both the years. Besides rainfall, the mean weekly average maximum temperature reduced to 22.7°C in 1st year and 20.7°C in 2nd year, while, minimum temperature dropped to 8.2°C in 1st season and 8.4°C in 2nd the season crop. The prevalence of dry period along with low temperature during this period helped in maturity of cane during both the years.

Crop condition

The health condition of crop was quite satisfactory during both the years. Because of favourable weather condition and proper agronomic management, no such major pest and disease infestation was observed during both the years. The crop was attacked by early shoot borer at early stage of crop growth during both the years, but it was effectively controlled by whorl application of Chloropyrifos 20 EC @ 5 liters ha⁻¹. Since, some prophylactic measures were taken in case of pest and diseases, therefore the incidence of pest and disease was very negligible during both the years of experimentation.

4.1 Growth parameters of sugarcane

The data pertaining to growth parameters as well as some growth indices viz., total number of shoots, number of shoots plant⁻¹, number of physiologically active leaves plant⁻¹, plant height, leaf area shoot⁻¹, leaf area index, leaf area duration, crop growth rate, relative growth rate, dry matter production by above ground portion, root length and root dry weight, chlorophyll content, green seeker NDVI, crop canopy temperature were recorded during 2017-18 and 2018-19 and presented in details.

4.1.1 Total number of shoots (‘000 ha⁻¹)

Data regarding the total number of shoots as influenced by crop establishment techniques and integrated nutrient management are presented in Table 4.1 and corresponding analyses of variance are appended in Appendix I.

Shoot population is one of the important criteria in sugarcane which govern the millable cane and ultimately cane yield. In both of the years of experimentation, the total shoot populations gradually increased and reached the maximum value at 180 DAP and thereafter, it gradually decreased with the advancement of crop growth.

Effect of crop establishment techniques

The total number shoots recorded at periodical intervals *i.e.* 90, 120, 150, 180, 210 and 240 DAP were significantly influenced by the crop establishment techniques in both the years except at 90 DAP.

During the early stages of crop growth *i.e.* 120 and 150 DAP, although the planting of bud chip seedling at 120 cm x 60 cm (M_3) exhibited significantly higher number of shoots (95.41 and 117.78 '000 ha⁻¹, respectively, during 2017-18; 93.40 and 115.64 '000 ha⁻¹, respectively, during 2018-19) but was at par with planting of bud chip seedling at 90 cm x 60 cm (M_2) (92.16 and 112.48 '000 ha⁻¹, respectively, during 2017-18; 90.13 and 111.16 '000 ha⁻¹, respectively, during 2018-19). But, both of them recorded significantly higher number of shoots as compared to the conventional method of planting (M_1) (76.64 and 95.38 '000 ha⁻¹, respectively, during 2017-18; 74.34 and 92.24 '000 ha⁻¹, respectively, during 2018-19). The insignificant difference between M_3 and M_2 at 120 and 150 DAP might be due to proper and early establishment of seedlings under both the techniques which helped in early shoots development, while, in case of conventional method, competition among the buds for germination under natural environment delayed the germination process and subsequently the shoot development.

At 180 DAP, planting of bud chip seedling at 120 cm x 60 cm (M_3) recorded significantly higher number of total shoots (146.88 and 142.56 '000 ha⁻¹) as compared to planting of bud chip seedling at 90 cm x 60 cm (M_2) (132.54 and 130.74 '000 ha⁻¹) as well as conventional method of planting (M_1) (124.65 and 121.25 '000 ha⁻¹) during 2017-18 and 2018-19, respectively. However, M_1 and M_2 were found to be at par in effect during both the years. Maximum number of shoots were obtained in all the crop establishment techniques during this stage and after that it started to decline.

Similarly, at 210 and 240 DAP, significantly higher number of shoots (134.70 and 127.76 '000 ha⁻¹, respectively, during 2017-18; 132.56 and 126.48 '000 ha⁻¹, respectively, during 2018-19) were registered under the planting of bud chip seedling at 120 cm x 60 cm (M_3) as compared to planting of bud chip seedling at 90 cm x 60 cm (M_2) (122.88 and 113.62 '000 ha⁻¹, respectively, during 2017-18; 120.42 and 112.68 '000 ha⁻¹, respectively, during 2018-19) and conventional method (M_1) (116.43 and 106.11 '000 ha⁻¹, respectively during 2017-18 ; 113.56 and 103.44 '000 ha⁻¹, respectively, during 2018-19). But, no significant difference in shoot population was observed between M_1 and M_2 during both the stages of crop growth in both the years of

investigation. The early canopy closures under both the techniques *i.e.* M_1 and M_2 restricted the development of new shoots as well as increased the mortality of tillers due to insufficient spacing which affected the light interception. While, in case of planting of bud chip seedling at 120 cm x 60 cm (M_3), the wider spacing helped in more penetration of light into the crop canopy that resulted in development of more number of shoots throughout the crop growing period. Sugeerthi *et al.* (2018) also reported higher shoot population due to planting of bud chip seedling technique as compared to single and double budded setts. Pawar *et al.* (2005) also reported significant variation in shoot population due to various inter settling spacing.

Effect of integrated nutrient management

Different integrated nutrient management practices showed significant variation in shoot population at all the crop growing stages other than 90 DAP in both the years. Result revealed that integrated nutrient management practices recorded significantly more number of shoots as compared to sole application of inorganic fertilizers (100% RDF) in all the recorded periods in both the years.

At early growth stages *i.e.* 120 and 150 DAP, significantly higher number of shoots were obtained due to integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers 10 kg ha⁻¹ (F_2) (90.44 and 111.77 '000 ha⁻¹, respectively, during 2017-18; 88.56 and 109.31 '000 ha⁻¹, respectively, during 2018-19) which was found to be at par with all the treatments comprised of both organic as well as inorganic sources of nutrients *viz.*, 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F_3) (89.31 and 110.92 '000 ha⁻¹, respectively, in 1st year; 87.20 and 108.88 '000 ha⁻¹, respectively, in 2nd year), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F_4) (88.75 and 109.88 '000 ha⁻¹, respectively, during in 1st year; 86.67 and 107.92 '000 ha⁻¹, respectively, in 2nd year) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ (F_5) + green manuring of cowpea (87.64 and 108.87 '000 ha⁻¹, respectively, in 1st year; 85.86 and 106.74 '000 ha⁻¹, respectively, in 2nd year). But, all of them recorded significantly higher values as compared to the application of 100% RDF through inorganic fertilizers (F_1) (84.12 and 101.28'000 ha⁻¹, respectively, during in 1st year; 81.50 and 98.86 '000 ha⁻¹, respectively, in 2nd year).

At 180 DAP, maximum number of shoots of 140.71 '000 ha⁻¹ during 2017-18 and 135.32 '000 ha⁻¹ during 2018-19 were obtained under the integrated supply

of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers 10 kg ha⁻¹ (F₂) which was found to be at par with 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (139.11 '000 ha⁻¹ during 2017-18 and 134.41 '000 ha⁻¹ during 2018-19) and 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (136.52 '000 ha⁻¹ during 2017-18 and 133.78 '000 ha⁻¹ during 2018-19), but superior to the application of 100% RDF (F₁) (122.34 '000 ha⁻¹ during 2017-18 and 121.54 '000 ha⁻¹ during 2018-19) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (134.77 '000 ha⁻¹ during 2017-18 and 132.19 '000 ha⁻¹ during 2018-19). But, F₃, F₄ and F₅ were found to be at par in effect during both the years.

In case of number of shoots recorded at 210 and 240 DAP; significantly higher number of shoots were also obtained under the integrated application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers 10 kg ha⁻¹ (F₂) (130.40 and 120.43 '000 ha⁻¹, respectively, in 1st year; 127.51 and 118.26 '000 ha⁻¹, respectively, in 2nd year) which was found to be at par with 100% RDF + green manuring of cowpea + enriched compost @ 1 t ha⁻¹ (F₃) (129.45 and 118.27 '000 ha⁻¹, respectively, in 1st year; 126.34 and 116.82 '000 ha⁻¹, respectively, in 2nd year) and 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (126.67 and 116.82 '000 ha⁻¹, respectively, in 1st year; 124.77 and 114.52 '000 ha⁻¹, respectively, in 2nd year), but found superior to the treatment receiving 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (125.57 and 115.22 '000 ha⁻¹, respectively, in 1st year; 122.45 and 113.86 '000 ha⁻¹, respectively, in 2nd year). At both the stages of crop growth, all the integrated nutrient management treatments recorded significantly higher total number of shoots than the treatment receiving 100% RDF (F₁) through inorganic fertilizers (111.22 and 107.28 '000 ha⁻¹, respectively, in 1st year; 109.85 and 106.25 '000 ha⁻¹, respectively, in 2nd year). However, the effect of F₃ and F₄, F₄ and F₅ were found to be at par at 210 DAP, while, the treatment F₃, F₄ and F₅ were found at par with each other at 240 DAP during both the years.

The maximum number of total shoots obtained under F₂ might be due to suitable combination of nutrients that helped in development of more number of shoots. Apart from optimal dose of inorganic fertilizers, the incorporation of green manuring crops, application of vermicompost along biofertilizers created congenial soil environment for development of shoots under this particular treatment.

Table 4.1. Effect of crop establishment technique and integrated nutrient management on total number of shoots in sugarcane

Treatments	Total number shoots ('000 ha ⁻¹)											
	2017-18						2018-19					
	Days after planting (DAP)						Days after planting (DAP)					
	90	120	150	180	210	240	90	120	150	180	210	240
Crop establishment techniques (M)												
M ₁ : Conventional method	55.07	76.64	95.38	124.65	116.43	106.11	54.12	74.34	92.24	121.25	113.56	103.44
M ₂ : Bud chip seedling at 90 cm x 60 cm	56.84	92.16	112.48	132.54	122.88	113.62	56.94	90.13	111.16	130.74	120.42	112.68
M ₃ : Bud chip seedling at 120 cm x 60 cm	55.42	95.41	117.78	146.88	134.70	127.76	54.67	93.40	115.64	142.56	132.56	126.48
SEm±	1.98	1.74	2.61	3.53	2.19	2.28	2.01	1.58	2.11	2.52	2.30	2.37
CD (P=0.05)	NS	6.84	10.24	13.85	8.62	8.94	NS	6.18	8.30	9.88	9.05	9.28
Integrated nutrient management (F)												
F ₁ : 100% RDF	54.22	84.12	101.28	122.34	111.22	107.28	54.34	81.50	98.86	121.54	109.85	106.25
F ₂ : 100% RDF + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	57.48	90.44	111.77	140.71	130.40	120.43	56.80	88.56	109.31	135.32	127.51	118.26
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	56.22	89.31	110.92	139.11	129.45	118.27	55.22	87.20	108.88	134.41	126.34	116.82
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	55.61	88.75	109.88	136.52	126.67	116.82	54.97	86.67	107.92	133.78	124.77	114.52
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	55.32	87.64	108.87	134.77	125.57	115.22	54.84	85.86	106.74	132.19	122.45	113.86
SEm±	0.88	1.02	1.02	1.58	1.30	1.26	0.74	0.97	0.92	0.94	1.05	1.32
CD (P=0.05)	NS	2.98	2.98	4.61	3.78	3.68	NS	2.82	2.68	2.78	3.08	3.87
Interaction (M x F)												
SEm±	1.52	1.77	1.78	2.76	2.24	2.18	1.28	1.68	1.60	1.64	1.82	2.30
CD (P=0.05)	NS	NS	NS	S	S	NS	NS	NS	NS	S	S	NS

Note: RDF: Recommended dose of fertilizer; GM: Green manuring; VC: Vermicompost; EC: Enriched compost; BF: Biofertilizers; SEm ±: Standard error of mean; CD: Critical difference, S: Significant; NS: Non significant

Table 4.1.1. Interaction effect between the crop establishment techniques and integrated nutrient management on total numbers of shoots ('000 ha⁻¹) at 180DAP

	2017-18					2018-19				
	F ₁	F ₂	F ₃	F ₄	F ₅	F ₁	F ₂	F ₃	F ₄	F ₅
M ₁ : Conventional method	116.55	127.73	128.00	126.32	124.67	108.64	127.25	124.27	123.35	122.75
M ₂ : Bud chip seedling at 90 cm x 60 cm	123.33	141.57	136.33	130.83	130.58	126.61	131.17	132.45	131.61	130.87
M ₃ : Bud chip seedling at 120 cm x 60 cm	126.74	152.80	153.00	152.41	149.07	129.38	147.55	146.52	146.38	142.95
			SEm±		CD (P=0.05)		SEm±		CD (P=0.05)	
M at the same level of F			2.76		8.07		2.24		6.54	
F at the same or different levels of M			3.91		11.42		2.35		6.87	

Note : F₁: 100% RDF; F₂: 100%RDF+green manuring of cowpea + vermicompost @1 t ha⁻¹ + biofertilizers @ 10 kg ha⁻¹; F₃: 100% RDF + green manuring of cowpea + enriched compost @ 1 t ha⁻¹; F₄: 75% RDF + FYM @ 5 t ha⁻¹ + green manuring of cowpea + vermicompost @ 1 t ha⁻¹ + biofertilizers @ 10 kg ha⁻¹; F₅: 75% RDF + FYM @ 5 t ha⁻¹ + green manuring of cowpea + enriched compost @ 1 t ha⁻¹

Table 4.1.2. Interaction effect between the crop establishment techniques and integrated nutrient management on total numbers of shoots ('000 ha⁻¹) at 210 DAP

	2017-18					2018-19				
	F ₁	F ₂	F ₃	F ₄	F ₅	F ₁	F ₂	F ₃	F ₄	F ₅
M ₁ : Conventional method	105.12	122.27	120.67	117.99	116.13	101.58	120.07	116.80	114.78	114.59
M ₂ : Bud chip seedling at 90 cm x 60 cm	112.73	128.14	127.66	122.88	121.74	111.87	124.6	124.79	124.01	116.87
M ₃ : Bud chip seedling at 120 cm x 60 cm	116.02	140.79	140.02	139.14	138.83	116.09	137.86	137.42	135.54	135.89
			SEm±		CD (P=0.05)		SEm±		CD (P=0.05)	
M at the same level of F			1.82		6.54		2.24		5.32	
F at the same or different levels of M			2.58		6.87		2.35		7.52	

Note : F₁: 100% RDF; F₂: 100%RDF+green manuring of cowpea + vermicompost @1 t ha⁻¹ + biofertilizers @ 10 kg ha⁻¹; F₃: 100% RDF + green manuring of cowpea + enriched compost @ 1 t ha⁻¹; F₄: 75% RDF + FYM @ 5 t ha⁻¹ + green manuring of cowpea + vermicompost @ 1 t ha⁻¹ + biofertilizers @ 10 kg ha⁻¹; F₅: 75% RDF + FYM @ 5 t ha⁻¹ + green manuring of cowpea + enriched compost @ 1 t ha⁻¹

The significant increase in total number of shoots under the integrated nutrient management than the sole inorganic fertilizers might be due to optimum supply of nutrients through mineralization from various sources of nutrients that might have helped in prolong and adequate release of nutrients to the crop which ultimately helped in emergence of more shoots as compared to sole application of inorganic fertilizers. Tyagi (2005) also reported that integration of 25% N through FYM + biofertilizers along with 100% RDF were found to be at par with integration with 75% RDF, but both of them were significantly higher than 100% RDF in terms of number of shoots ha^{-1} . Many researchers also reported significant improvement in total number of shoots due to combined effect of both organic and inorganic sources over 100% RDF through inorganic fertilizers (Kumar and Singh, 1999; Jeyaraman and Alagudural, 2003; Bokhtier and Sakurai, 2007).

Interaction effect

The interaction effect between the crop establishment techniques and integrated nutrient management was found to be significant on total numbers of shoots recorded at 180 and 210 DAP in both the years. The integrated application of different organic sources of nutrients along with 100% RDF and 75% RDF produced significantly more shoot population in all the crop established techniques than the 100% RDF. At 180 DAP, the maximum number of shoots ($153.00 \text{ '000 ha}^{-1}$) was obtained under the combined effect of planting of bud seedling at 120 cm x 60 cm and 100% RDF + enriched compost @ 1 t ha^{-1} + green manuring of cowpea (M_3F_3) during 2017-18, while, the planting of bud seedling at 120 cm x 60 cm along with application of 100% RDF + vermicompost @ 1 t ha^{-1} + green manuring of cowpea + biofertilizers 10 kg ha^{-1} (M_3F_2) produced the maximum value ($147.55 \text{ '000 ha}^{-1}$) during 2018-19 and both of them were found to be at par with M_3F_4 (152.41 and $146.38 \text{ '000 ha}^{-1}$) and M_3F_5 (149.07 and $142.95 \text{ '000 ha}^{-1}$) but superior over all other treatment combinations during both the years.

At 210 DAP, the maximum values (140.79 and $137.86 \text{ '000 ha}^{-1}$) were obtained under the combined effect of planting of bud chip seedling at 120 cm x 60 cm along with application of 100% RDF + vermicompost @ 1 t ha^{-1} + green manuring of cowpea + biofertilizers 10 kg ha^{-1} (M_3F_2) that was found to be at par with M_3F_3 (140.02 and $137.42 \text{ '000 ha}^{-1}$), M_3F_4 (139.14 and $135.54 \text{ '000 ha}^{-1}$) and M_3F_5 (138.83 and $135.89 \text{ '000 ha}^{-1}$) but superior to other treatment combinations during both the years.

The wider spacing between the seedlings and integrated supply of nutrients helped in development of more shoots population during both the years.

4.1.2 Number of shoots plant⁻¹

Data pertaining to the number of shoots plant⁻¹ recorded at different growth stages of sugarcane as influenced by crop establishment techniques and integrated nutrient management during both the years has been furnished in Table 4.2 and corresponding analyses of variance are appended in Appendix II.

The numbers of shoots plant⁻¹ showed an increasing trend with the advancement of crop growth and reached the maximum value at 180 DAP; thereafter, it started to decline in the later stage of crop growth *i.e.* at 210 DAP. The competition among the shoots for all the resources during the later stage of crop growth resulted in mortality of tillers which reduced the number of shoots plant⁻¹.

Effect of crop establishment techniques

A close perusal of data revealed that number of shoots plant⁻¹ recorded at periodical intervals *viz.*, 90, 150, 180 and 210 DAP showed significant variation due to different crop establishment techniques in both the years of investigation.

In early stage of crop growth *i.e.* at 90 DAP, the number of shoots plant⁻¹ recorded under the planting of bud chip seedling at 120 cm x 60 cm (M₃) was found to be at par with planting of bud chip seedling at 90 cm x 60 cm (M₂) during both the years. But, with the progress in crop growth, significant variation was observed among all the crop establishment techniques. Other than 90 DAP, at all the crop growing stages *i.e.* at 150, 180 and 210 DAP, M₃ *i.e.* planting of bud chip seedling at 120 cm x 60 cm recorded significantly higher number of shoots plant⁻¹ (9.48, 11.58 and 10.20; 9.32, 11.34 and 9.98) as compared to planting of bud chip seedling at 90 cm x 60 cm (M₂) (7.08, 8.14 and 7.17 ; 6.94, 7.87 and 7.01) and conventional method (M₁) (1.87, 3.76 and 3.08; 1.81, 3.70 and 3.02), during 2017-18 and 2018-19, respectively. However, the maximum number of shoots plant⁻¹ (11.58 and 11.34) was obtained at 180 DAP due to planting of bud chip seedling at 120 cm x 60 cm (M₃) which revealed significantly higher values as compared to the planting of bud chip seedling at 90 cm x 60 cm (M₂) (8.14 and 7.87) as well as conventional method of planting (M₁) (3.76 and 3.70) during 1st and 2nd year, respectively.

Table 4.2. Effect of crop establishment techniques and integrated nutrient management on number of shoots plant⁻¹ in sugarcane

Treatments	Number of shoots plant ⁻¹							
	2017-18				2018-19			
	Days after planting (DAP)				Days after planting (DAP)			
	90	150	180	210	90	150	180	210
Crop establishment techniques (M)								
M ₁ : Conventional method	1.28	1.87	3.76	3.08	1.20	1.81	3.70	3.02
M ₂ : Bud chip seedling at 90 cm x 60 cm	4.21	7.08	8.14	7.17	4.05	6.94	7.87	7.01
M ₃ : Bud chip seedling at 120 cm x 60 cm	4.44	9.48	11.58	10.20	4.31	9.32	11.34	9.98
SEm±	0.14	0.10	0.28	0.18	0.16	0.11	0.16	0.18
CD (P=0.05)	0.56	0.38	1.11	0.72	0.64	0.45	0.63	0.71
Integrated nutrient management (F)								
F ₁ : 100% RDF	3.15	5.82	7.14	6.18	3.08	5.68	7.00	6.01
F ₂ : 100% RDF + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	3.56	6.30	8.15	7.13	3.32	6.18	7.94	6.96
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	3.48	6.22	8.08	7.07	3.25	6.14	7.88	6.92
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	3.41	6.20	7.94	6.91	3.17	6.08	7.72	6.76
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	3.38	6.17	7.82	6.80	3.15	6.03	7.64	6.71
SEm±	0.05	0.05	0.09	0.12	0.05	0.06	0.08	0.13
CD (P=0.05)	NS	0.15	0.28	0.35	NS	0.18	0.24	0.37
Interaction (M x F)								
SEm±	0.08	0.09	0.16	0.21	0.09	0.11	0.14	0.22
CD (P=0.05)	NS	NS	S	S	NS	NS	S	S

Note: RDF: Recommended dose of fertilizer; GM: Green manuring; VC: Vermicompost; EC: Enriched compost; BF: Biofertilizers; SEm±: Standard error of mean; CD: Critical difference, S: Significant NS: Non significant

Table 4.2.1. Interaction between the crop establishment techniques and integrated nutrient management on total numbers of shoots plant⁻¹ at 180 DAP

	2017-18					2018-19				
	F ₁	F ₂	F ₃	F ₄	F ₅	F ₁	F ₂	F ₃	F ₄	F ₅
M ₁ : Conventional method	3.65	3.79	3.78	3.76	3.77	3.53	3.85	3.75	3.70	3.68
M ₂ : Bud chip seedling at 90 cm x 60 cm	7.68	8.45	8.35	8.11	8.10	7.76	8.14	8.09	7.80	7.54
M ₃ : Bud chip seedling at 120 cm x 60 cm	10.08	12.20	12.12	11.94	11.61	9.74	11.83	11.80	11.66	11.69
			SEm±		CD (P=0.05)		SEm±		CD (P=0.05)	
M at the same level of F			0.16		0.46		0.14		0.42	
F at the same or different levels of M			0.30		0.87		0.18		0.54	

Note : F₁: 100% RDF; F₂: 100%RDF+green manuring of cowpea + vermicompost @1 t ha⁻¹ + biofertilizers @ 10 kg ha⁻¹; F₃: 100% RDF + green manuring of cowpea + enriched compost @ 1 t ha⁻¹; F₄: 75% RDF + FYM @ 5 t ha⁻¹ + green manuring of cowpea + vermicompost @ 1 t ha⁻¹ + biofertilizers @ 10 kg ha⁻¹; F₅: 75% RDF + FYM @ 5 t ha⁻¹ + green manuring of cowpea + enriched compost @ 1 t ha⁻¹

Table 4.2.2. Interaction between the crop establishment techniques and integrated nutrient management on total numbers of shoots plant⁻¹ at 210 DAP

	2017-18					2018-19				
	F ₁	F ₂	F ₃	F ₄	F ₅	F ₁	F ₂	F ₃	F ₄	F ₅
M ₁ : Conventional method	2.81	3.25	3.15	3.11	3.08	2.75	3.17	3.10	3.05	3.05
M ₂ : Bud chip seedling at 90 cm x 60 cm	7.06	7.44	7.39	7.10	6.84	6.90	7.23	7.24	6.94	6.74
M ₃ : Bud chip seedling at 120 cm x 60 cm	8.66	10.69	10.65	10.52	10.48	8.38	10.47	10.43	10.31	10.31
			SEm±		CD (P=0.05)		SEm±		CD (P=0.05)	
M at the same level of F			0.21		0.60		0.22		0.64	
F at the same or different levels of M			0.23		0.66		0.24		0.68	

Note : F₁: 100% RDF; F₂: 100%RDF+green manuring of cowpea + vermicompost @1 t ha⁻¹ + biofertilizers @ 10 kg ha⁻¹; F₃: 100% RDF + green manuring of cowpea + enriched compost @ 1 t ha⁻¹; F₄: 75% RDF + FYM @ 5 t ha⁻¹ + green manuring of cowpea + vermicompost @ 1 t ha⁻¹ + biofertilizers @ 10 kg ha⁻¹; F₅: 75% RDF + FYM @ 5 t ha⁻¹ + green manuring of cowpea + enriched compost @ 1 t ha⁻¹

The development of more number of shoots under the planting of bud chip seedling at 120 cm x 60 cm (M₃) might be due to appropriate spacing maintained within the seedlings that facilitated more interception of solar radiation as well effective utilization of all resources due to less inter plant competition. The production of more number of shoots plant⁻¹ under wider spacing was also reported by Rao (1990) and Patel *et al.* (2014).

The utmost care provided to the bud chip seedlings in nursery bed resulted in better root proliferation that helped in proper establishment of seedlings in main field. Hence, the early establishment of seedlings and proper allocation of resources due to adequate spacing might have helped in development of more shoots in case of bud chip seedling planted at 120 cm x 60 cm. Chilawal *et al.* (2018) also reported that number of shoots plant⁻¹ was significantly influenced by plant spacing and effect was more pronounced at later stages of crop growth than the early stages. Samant (2017) also reported higher number of shoots plant⁻¹ (17.3) under the bud chip technology as compared to conventional method (9.2).

Effect of integrated nutrient management

During both the years of investigation, significant variation in number of shoots plant⁻¹ was observed due to different integrated nutrient management practices during all the recorded periods except 90 DAP (Table 4.2).

The integrated nutrient management practices recorded significantly more number of shoots plant⁻¹ as compared to 100% RDF (F₁) at all the crop growth stages *i.e.* at 150, 180 and 210 DAP during both the years. Data recorded at 150 DAP revealed that although the integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) produced significantly higher number of shoots plant⁻¹ (6.30 and 6.18, during 2017-18 and 2018-19, respectively) as compared to 100 % RDF (F₁) (5.82 and 5.68, during 2017-18 and 2018-19, respectively) but found to be at par with the rest of treatments during both the years.

At 180 DAP, integrated supply of 100% RDF + green manuring of cowpea + vermicompost @ 1 t ha⁻¹ + biofertilizers @ 10 kg ha⁻¹ (F₂) also recorded maximum number of shoots plant⁻¹ (8.15 and 7.94) which were found to be at par with 100% RDF + green manuring of cowpea + enriched compost @ 1 t ha⁻¹ (F₃) (8.08 and 7.88) and 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (7.94 and 7.72), but superior to the treatments

receiving 100% RDF (F₁) (7.14 and 7.00) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (7.82 and 7.64) during 2017-18 and 2018-19, respectively. However, F₃ was found to be at par with F₄ and F₅ during both the years. At this particular stage, the integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded 14.15 and 13.43% higher number of shoots plant⁻¹ as compared to 100% RDF (F₁) during 2017-18 and 2018-19, respectively. Apart from nutrient supplied from optimal dose of inorganic fertilizers, the other nutrient sources like vermicompost released some growth hormones that helped in development of more number of shoots per plant. Besides this, the incorporation of green manure crop, biofertilizers helped in improvement in soil properties for better release of nutrients. The cumulative effect of all these nutrients ultimately resulted in better crop growth.

At 210 DAP, treatment comprised of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher number of shoots (7.13 and 6.96) but found to be at par with all the treatments except 100% RDF (F₁) (6.18 and 6.01) during 1st and 2nd year, respectively. The better supply of nutrients to the crop under the integrated supply of nutrients through organic as well as inorganic sources might have helped in development of more number of shoots plant⁻¹ as compared to 100% RDF. Soomro *et al.* (2013) also reported significantly higher number of shoots plant⁻¹ (6.55) due to integrated supply of 75% RDF + pressmud @ 20 t ha⁻¹ which was superior to 100% RDF (5.33) supplied through inorganic fertilizers.

Interaction effect

The interaction effect between crop establishment techniques and integrated nutrient management was found significant on number of shoots plant⁻¹ recorded at 180 and 210 DAP during both the years of experimentation (Table 4.2.1 and 4.2.2).

The integrated nutrient management recorded significantly more number of shoots plant⁻¹ as compared to 100% RDF under all the crop establishment techniques. However, planting of bud chip seedling at 120 cm x 60 cm along with the treatments receiving integrated nutrient management *viz.*, M₃F₂, M₃F₃, M₃F₄, M₃F₅ produced significantly more number of shoots plant⁻¹ as compared to combined effect of other crop establishment techniques and integrated nutrient management. However, the

maximum number of shoots plant⁻¹ *i.e.* 12.20 during 2017-18 and 11.83 during 2018-19 were obtained at 180 DAP due to the combined effect of planting of bud chip seedling at 120 cm x 60 cm along with integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (M₃F₂).

Similarly, at 210 DAP, the same treatment combination (M₃F₂) also produced the maximum number of shoots plant⁻¹ *i.e.* 10.69 during 2017-18 and 10.47 during 2018-19, which was found to be at par with M₃F₃ (10.65 and 10.43), M₃F₄ (10.52 and 10.31) and M₃F₅ (10.48 and 10.31) during 1st and 2nd year, respectively. During both stages of crop growth *i.e.* at 180 and 210 DAP, the lowest number of shoots plant⁻¹ was obtained under the combined effect of conventional method along with 100% RDF (M₁F₁) (3.65 and 2.81, respectively, during 2017-18; 3.53 and 2.75, respectively, 2018-19). The suitable planting technique in conjunction with proper integration of nutrients might have helped in development of more number of shoots plant⁻¹.

4.1.3 Number of physiologically active leaves shoot⁻¹

The data in respect of number of physiologically active leaves shoot⁻¹ as affected by crop establishment techniques and integrated nutrient management are presented in Table 4.3 and their corresponding analyses of variance are appended in Appendix III.

The number of physiologically active leaves increased gradually with the advancement of crop growth stages that reached maximum value at 240 DAP and thereafter, decreased towards maturity. The rate of development of new leaves were very slow up to 210 DAP that progressively increased at a faster rate and reached maximum at 240 DAP and subsequently decreased during both the years of study.

Effect of crop establishment techniques

The different crop establishment techniques showed significant variation in number of physiologically active leaves shoot⁻¹ recorded at different crop growing periods *viz.*, 180, 210, 240 and 270 DAP in both the years of investigation except 120 and 150 DAP. The insignificant difference during early stage of crop growth *i.e.* at 120 and 150 DAP might be due to prevalence of low temperature and dry period that might have affected the rate of development of new leaves.

Table 4.3. Effect of crop establishment techniques and integrated nutrient management on number of physiologically active leaves shoot⁻¹ in sugarcane

Treatments	Number of physiological active leaves shoot ⁻¹											
	2017-18						2018-19					
	Days after planting (DAP)						Days after planting (DAP)					
	120	150	180	210	240	270	120	150	180	210	240	270
Crop establishment technique (M)												
M ₁ :Conventional method	5.16	5.58	7.14	8.61	11.51	10.51	5.04	5.23	7.02	8.58	11.18	10.22
M ₂ : Bud chip seedling at 90 cm x 60 cm	5.18	5.64	7.52	9.14	12.30	10.80	5.08	5.26	7.27	8.97	11.64	10.63
M ₃ :Bud chip seedling at 120 cm x 60 cm	5.24	5.76	8.24	9.72	12.84	11.21	5.13	5.43	7.83	9.68	12.54	11.08
SEm±	0.11	0.13	0.19	0.20	0.23	0.11	0.12	0.15	0.16	0.21	0.24	0.15
CD (P=0.05)	NS	NS	0.76	0.80	0.88	0.46	NS	NS	0.60	0.82	0.94	0.60
Integrated nutrient management (F)												
F ₁ : 100% RDF	5.14	5.50	7.11	8.74	11.58	10.42	4.92	5.22	6.82	8.53	11.22	10.17
F ₂ : 100% RDF + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	5.24	5.76	7.96	9.41	12.62	11.06	5.16	5.36	7.60	9.32	12.11	10.86
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	5.20	5.72	7.78	9.32	12.45	10.94	5.14	5.31	7.55	9.22	12.05	10.83
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	5.22	5.66	7.74	9.22	12.22	10.92	5.11	5.27	7.48	9.18	11.84	10.75
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	5.20	5.65	7.68	9.15	12.20	10.88	5.08	5.26	7.42	9.13	11.77	10.64
SEm±	0.07	0.08	0.10	0.11	0.16	0.11	0.06	0.08	0.10	0.13	0.18	0.15
CD (P=0.05)	NS	NS	0.29	0.30	0.47	0.32	NS	NS	0.30	0.37	0.53	0.44
Interaction (M x F)												
SEm±	0.12	0.13	0.17	0.18	0.28	0.18	0.11	0.14	0.17	0.22	0.31	0.26
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: RDF: Recommended dose of fertilizer; GM: Green manuring; VC: Vermicompost; EC: Enriched compost; BF: Biofertilizers; SEm±: Standard error of mean; CD: Critical difference, NS: Non significant

Throughout the crop growing period, the number of physiologically active leaves shoot⁻¹ under different crop establishment techniques ranged from 5.16 to 12.84 and 5.04 to 12.54 during 2017-18 and 2018-19, respectively. Cheero-Nayamath *et al.* (2000) also reported that the total number of expanded functional leaves plant⁻¹ ranged from 6 to 13 in sugarcane. During other crop growing stages *i.e.* at 180, 210, 240 and 270 DAP, planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded significantly higher number of physiologically active leaves (8.24, 9.72, 12.84 and 11.21, respectively, during 2017-18; 7.83, 9.68, 12.54 and 11.08, respectively, during 2018-19) as compared to the conventional method (M₁) (7.14, 8.61, 11.51 and 10.51, respectively, during 2017-18; 7.02, 8.58, 11.18 and 10.22, respectively, during 2018-19) which were found to be at par with planting of bud chip seedling at 90 cm x 60 cm (M₂) (7.52, 9.14, 12.30 and 10.80, respectively, during 2017-18; 7.27, 8.97, 11.64 and 10.63, respectively, during 2018-19). However, planting of bud chip seedling at 90 cm x 60 cm (M₂) and conventional method (M₁) was found to be at par with each other throughout crop growing period during both the years of investigation.

Significantly higher number of physiologically active leaves shoot⁻¹ under the planting of bud chip seedling at 120 cm x 60 cm (M₃) might be due to wider spacing between the seedlings that allowed more penetration of light which might have created congenial environment for production of more number of leaves shoot⁻¹. Besides this, increase in plant height might be responsible for increase in number of leaves plant⁻¹. Chiluwal *et al.* (2018) also reported more number of leaves plant⁻¹ under wider planting (1.83 m x 0.91 m) as compared to narrow planting of sugarcane (1.2 m x 0.6 m).

Effect of integrated nutrient management

Data presented in Table 4.3 showed significant variation in number of physiologically active leaves shoot⁻¹ except 120 and 150 DAP due to different integrated nutrient management during both the years. Throughout the crop growing period, the integrated supply of both organic and inorganic sources of nutrients significantly increased the number of physiologically active leaves shoot⁻¹ in comparison to 100% RDF during both the years.

At 180 DAP, application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher number of physiologically active leaves of 7.96 during 2017-18 and 7.60 during

2018-19 which was found to be at par with the treatments receiving 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (7.78 and 7.55), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (7.74 and 7.48) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (7.68 and 7.42) during 1st and 2nd year, respectively.

Similarly, at 210, 240 and 270 DAP, the treatment comprised of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher number of physiologically active leaves (9.41, 12.62, and 11.06, respectively, during 2017-18; 9.32, 12.11 and 10.86, respectively, during 2018-19) which was found to be at par with the treatments receiving 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (9.32, 12.45 and 10.94, respectively, during 2017-18; 9.22, 12.05 and 10.83, respectively, during 2018-19), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (9.22, 12.22 and 10.92, respectively, during 2017-18; 9.18, 11.84 and 10.75, respectively, during 2018-19) and 75% RDF + FYM @ 5 t ha⁻¹ + green manuring of cowpea + enriched compost @ 1 t ha⁻¹ (F₅) (9.15, 12.20 and 10.88, respectively, during 2017-18; 9.13, 11.7 and 10.64, respectively, during 2018-19). Whereas, the application of 100% RDF (F₁) recorded the lowest number of physiologically active leaves (8.74, 11.58 and 10.42, respectively, during 2017-18; 8.53, 11.22 and 10.17, respectively, during 2018-19) in all the respective crop growth stages.

The increased values in respect of number of physiologically active leaves clearly indicated the beneficial effect of adding organic manures to the soil in conjunction with chemical fertilizers that increased the availability of nutrients to the crop due to improvement in physical and biological properties of soil (Murarkar *et al.*, 1998).

Interaction effect

The interaction effect between crop establishment techniques and integrated nutrient management in terms of number of physiologically active leaves shoot⁻¹ was found to be non-significant during both the years.

4.1.4 Plant height (cm)

Plant height is an important growth parameter that determined the length of millable cane. In the present investigation, data pertaining to plant height recorded at

different growth stages of sugarcane *i.e.* 150, 210, 270 and 330 DAP as affected by crop establishment techniques and integrated nutrient management are presented in Table 4.4 and corresponding analyses of variance are appended in Appendix IV.

The plant height was found to be very less up to 150 DAP and after that it progressively increased with the advancement of crop growth and reached the maximum at 330 DAP during both the years. In early stage of crop growth, nutrients were mainly utilized for development of tillers rather than plant height due to which plant height was found to be comparatively less in all the treatments.

Effect of crop establishment techniques

The different crop establishment techniques significantly influenced the plant height recorded at different crop growing periods in both the years. At 150 DAP, significantly higher plant height of 26.98 cm during 2017-18 and 24.38 cm during 2018-19 was attained due to planting of bud chip seedling at 120 cm x 60 cm (M_3) which was at par with planting of bud chip seedling at 90 cm x 60 cm (M_2) (26.20 and 23.47 cm) and both of them were found superior to the conventional method (M_1) (22.15 and 18.81 cm) during 2017-18 and 2018-19, respectively. Similarly, at 210 DAP, the planting of bud chip seedling at 120 cm x 60 cm (M_3) recorded significantly higher plant height (76.38 and 72.22 cm, during 2017-18 and 2018-19, respectively) as compared to conventional method (M_1) (65.48 and 60.51 cm, during 2017-18 and 2018-19, respectively), but was par with planting of bud chip seedling at 90 cm x 60 cm (M_2) (70.37 and 64.28 cm, during 2017-18 and 2018-19, respectively).

In subsequent growth stages, *i.e.* at 270 and 330 DAP, plant height recorded under the planting of bud chip seedling at 120 cm x 60 cm (M_3) (163.42 and 267.93 cm, respectively, during 2017-18; 158.58 and 256.60 cm, respectively, during 2018-19) was found significantly higher than the planting of bud chip seedling at 90 cm x 60 cm (M_2) (152.68 and 246.27 cm, respectively, during 2017-18; 146.34 and 236.84 cm, respectively, during 2018-19) and conventional method (M_1) (148.56 and 241.53 cm, respectively, during 2017-18; 140.22 and 230.46 cm, respectively, during 2018-19). But no significant difference in plant height was observed between M_1 and M_2 at 210, 270 and 330 DAP during both the years of investigation. In case of M_2 and M_3 , bud chip seedling raised under controlled environment helped in early establishment of plant in main field and ultimately helped in attaining more plant height as compared to conventional method of planting. But as the growth progressed,

Table 4.4. Effect of crop establishment techniques and integrated nutrient management on plant height in sugarcane

Treatments	Plant height (cm)							
	2017-18				2018-19			
	Days after planting (DAP)				Days after planting (DAP)			
	150	210	270	330	150	210	270	330
Crop establishment techniques (M)								
M ₁ : Conventional method	22.15	65.48	148.56	241.53	18.81	60.51	140.22	230.46
M ₂ : Bud chip seedling at 90 cm x 60 cm	26.20	70.37	152.68	246.27	23.47	64.28	146.34	236.84
M ₃ : Bud chip seedling at 120 cm x 60 cm	26.98	76.38	163.42	267.93	24.38	72.22	158.58	256.60
SEm±	0.73	2.05	2.41	5.12	0.64	2.17	2.45	4.20
CD (P=0.05)	2.86	8.07	9.56	20.11	2.51	8.52	9.63	16.48
Integrated nutrient management (F)								
F ₁ : 100% RDF	22.18	61.41	141.44	242.33	20.11	57.02	136.16	230.28
F ₂ : 100% RDF + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	27.35	75.14	160.72	258.72	23.60	70.20	153.78	247.88
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	27.06	74.55	159.48	255.00	23.49	68.95	152.18	244.72
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	25.85	72.68	157.60	254.22	22.04	67.52	150.54	242.83
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	25.51	69.94	155.18	249.38	21.86	64.66	148.68	240.78
SEm±	0.37	0.98	1.55	3.28	0.35	1.04	1.46	3.54
CD (P=0.05)	1.08	2.86	4.53	9.58	1.03	2.93	4.27	10.34
Interaction (M x F)								
SEm±	0.64	1.70	2.69	5.68	0.61	1.74	2.53	6.14
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Note: RDF: Recommended dose of fertilizer; GM: Green manuring; VC: Vermicompost; EC: Enriched compost; BF: Biofertilizers; SEm±: Standard error of mean; CD: Critical difference, NS: Non significant

the competition between plants due to closer spacing in both conventional method as well as planting of bud chip seedling at 90 cm x 60 cm retarded the crop growth and no significant variation in plant height was observed between them. On the other hand, planting of bud chip seedling at 120 cm x 60 cm spacing (M₃) might have helped in efficient utilization of solar light and other resources due to sufficient spacing between the plants resulting in maximum plant height throughout the crop growing period.

Effect of integrated nutrient management

The plant height recorded at different crop growth stages showed significant variation due to different integrated nutrient management practices during both the years of investigation. The treatments following the integrated nutrient management practices recorded significantly more plant height as compared to sole application of 100% RDF through inorganic fertilizers during both the years.

In early stage of crop growth *i.e.* at 150 DAP, the treatment comprised of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher plant height of 27.35 cm during 2017-18 and 23.60 cm during 2018-19 which was at par with 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (27.06 and 23.49 cm) and both of them were superior to the treatment receiving 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (25.85 and 22.04 cm) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (25.51 and 21.86 cm), in the respective years. The availability of more nutrients under the optimal dose of inorganic fertilizers along with organic sources helped in more elongation of plant as compared to sub-optimal dose.

At 210 DAP, significantly higher plant height of 75.14 cm during 2017-18 and 70.20 cm during 2018-19 was attained due to the application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) which was at par with all the treatments other than 100% RDF (F₁) (61.41 and 57.02 cm, during 2017-18 and 2018-19, respectively) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (69.94 and 64.66 cm, during 2017-18 and 2018-19, respectively). The effect of F₃ and F₄, F₄ and F₅ was found to be at par during both the years.

At 270 DAP, treatment receiving 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) revealed significantly higher plant height of 160.72 cm during 2017-18 and 153.78 cm during 2018-19 which were found to be at par with 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (159.48 and 152.18 cm) and 75% RDF+ FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (157.60 and 150.54 cm) during first and second year, respectively. Moreover, the plant height recorded under F₃, F₄ and F₅ was found to be at par with each other during both the years.

In later stage of crop growth *i.e.* at 330 DAP, significantly higher plant height was obtained due to the application 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) which was found to be at par with all the treatments receiving both organic as well as inorganic sources of nutrients *viz.*, 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (255.00 and 244.72 cm), 75% RDF+ FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (254.22 and 242.83 cm) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (249.38 and 240.78 cm) during 1st and 2nd year, respectively. All of them were found to be significantly higher as compared to the sole application of inorganic fertilizers *i.e.* 100% RDF (F₁) (242.33 in 1st year and 230.28 cm in 2nd year).

The use of organic sources of nutrients, biofertilizers along with chemical fertilizers helped in uniform supply of nutrients through mineralization process that resulted in higher plant height. On the other hand, 100% RDF (F₁) failed to provide the sufficient amount of nutrients throughout the crop growing period due to loss of nutrients through various factors that greatly reduced the plant height. However, the maximum plant height was obtained due to integration of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) in all the crop growing periods during both the years of investigation. The suitable combination of various sources of nutrients such as vermicompost, biofertilizers, and green manuring of cowpea along with optimal dose of inorganic fertilizers might have helped in supply of more amounts of nutrients to the crop that resulted in better crop growth. Besides the supply of nutrients, the release of growth hormones like auxins, cytokinins, and gibberalic acid like substances from *Azotobacter* (Wani *et al.*, 2013) and vermicompost (Krishnamoorthy and Vajrabhiah, 1986) might be responsible for

increased the plant height. Kumar *et al.* (2019) also reported significant increase in plant height (2.91 m) due to integration of FYM @ 10 t ha⁻¹, bio-fertilizer along with 100% recommended dose of NPK over the sole application of 100% NPK (2.67 m). Similar finding was also reported by Tyagi *et al.* (2012).

Interaction effect

No significant difference in plant height was observed due to interaction effect between the crop establishment techniques and integrated nutrient management during both the years.

4.1.5 Leaf area shoot⁻¹ (cm²)

Data in respect of leaf area shoot⁻¹ recorded at different crop growth stages *i.e.* at 150, 180, 210, 240, 300 and 390 DAP as influenced by crop establishment techniques and integrated nutrient management are presented in Table 4.5 and corresponding analyses of variance are appended in Appendix V.

In early crop growth stage *i.e.* at 150 DAP, the development of leaf area shoot⁻¹ was very slow which rapidly increased during grand growth stage and again declined towards maturity. The low temperature during the early crop growth stage might have restricted the leaf area expansion. However, with the advancement of crop growth the leaf area shoot⁻¹ progressively increased and reached the maximum at 240 DAP and decreased at subsequent crop growth stages during both the years.

Effect of crop establishment techniques

The different crop establishment techniques showed significant variation on leaf area shoot⁻¹ recorded at different crop growth stages except 150, 330 and 390 DAP during both the years. The insignificant difference in early stage of crop growth *i.e.* at 150 DAP might be due to less competition among the plants for nutrients. On the other hand, senescence of most of the physiologically active leaves in later stages of crop growth as well as closure of crop canopy might be responsible for insignificant difference at 330 and 390 DAP under different crop establishment techniques.

Table 4.5. Effect of crop establishment techniques and integrated nutrient management on leaf area shoot⁻¹ in sugarcane

Treatments	Leaf area shoot ⁻¹ (cm ²)											
	2017-18						2018-19					
	Days after planting (DAP)						Days after planting (DAP)					
	150	180	210	240	300	390	150	180	210	240	300	390
Crop establishment techniques (M)												
M ₁ : Conventional method	725.18	1406.32	2701.22	4120.51	3990.88	1515.88	700.32	1311.64	2682.14	3981.38	3866.06	1524.33
M ₂ : Bud chip seedling at 90 cm x 60 cm	727.62	1502.17	2941.38	4457.63	4064.26	1544.07	704.68	1401.72	2861.20	4343.05	3971.34	1533.69
M ₃ : Bud chip seedling at 120 cm x 60 cm	750.48	1565.68	3272.86	4765.77	4213.21	1636.18	708.32	1515.25	3157.00	4536.58	4161.62	1602.92
SEm±	13.13	29.43	85.84	86.99	64.22	45.48	15.58	29.44	85.89	74.56	105.96	43.81
CD (P=0.05)	NS	115.76	337.08	341.58	NS	NS	NS	116.05	337.28	292.78	NS	NS
Integrated nutrient management (F)												
F ₁ : 100% RDF	713.95	1416.34	2846.52	4298.52	3931.82	1537.54	683.14	1301.64	2721.44	4054.76	3758.22	1528.15
F ₂ : 100% RDF + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	754.79	1538.67	3078.34	4582.33	4182.69	1582.86	727.28	1476.12	3044.22	4426.45	4106.32	1574.36
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	746.60	1516.77	3033.21	4500.64	4143.26	1578.34	715.78	1442.34	2966.98	4359.52	4077.16	1570.16
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	733.86	1500.92	2960.18	4460.14	4104.83	1566.70	701.50	1417.96	2898.73	4312.07	4043.81	1551.32
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	724.95	1488.12	2940.88	4431.67	4084.60	1561.44	694.32	1414.63	2870.32	4282.33	4018.12	1544.25
SEm±	5.74	11.44	31.84	35.92	30.73	20.81	6.86	17.83	36.70	30.57	24.82	19.36
CD (P=0.05)	16.75	33.93	92.92	104.82	89.70	NS	20.02	52.04	107.08	89.22	72.42	NS
Interaction (M x F)												
SEm±	9.94	19.82	55.14	62.21	53.22	36.04	11.88	30.88	63.54	52.95	42.98	33.54
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: RDF: Recommended dose of fertilizer; GM: Green manuring; VC: Vermicompost; EC: Enriched compost; BF: Biofertilizers; SEm±: Standard error of mean; CD: Critical difference, NS: Non significant

At 180 and 210 DAP, the leaf area shoot⁻¹ recorded under the planting of bud chip seedling at 120 cm x 60 cm (M₃) (1565.68 and 3272.86 cm², respectively, during 2017-18; 1515.25 and 3157.00 cm², respectively, during 2018-19) was found to be at par with the planting of bud chip seedling at 90 cm x 60 cm (M₂) (1502.17 and 2941.38 cm², respectively, during 2017-18; 1401.72 and 2861.20 cm², respectively, during 2018-19) but significantly higher than the conventional method (M₁) (1406.32 and 2701.22 cm², respectively, during 2017-18; 1311.64 and 2682.14 cm², respectively, during 2018-19). Besides this, both M₁ and M₂ were found to be at par in effect during both the years of study.

At 240 DAP, planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded maximum leaf area shoot⁻¹ of 4765.77 cm² during 2017-18 and 4536.58 cm² during 2018-19, which were significantly higher as compared to conventional method of planting (M₁) (4120.51 and 3981.38 cm²), but at par with planting of bud chip seedling at 90 cm x 60 cm (M₂) (4457.63 and 4343.05 cm²) during 2017-18 and 2018-19, respectively. However, M₂ was found to be at par with M₁ during 2017-18, but found to be superior to M₁ during 2018-19.

The leaf area shoot⁻¹ is the function of number of physiologically active leaves as well as their magnitude of expansion which is mainly governed by the nutrient availability to the plants. The variation in shoot population and their competition for nutrients at different crop growth stages revealed variable results in leaf area shoot⁻¹ among the different crop establishment techniques. Obtaining of significantly higher values under planting of bud chip seedling at 120 cm x 60 cm (M₃) was due to maintenance of appropriate plant spacing between the seedlings that might have helped in more expansion of leaves resulting in more leaf area shoot⁻¹. Khalid *et al.* (2015) also reported higher leaf area shoot⁻¹ due to planting of bud chip seedling at 120 cm row spacing followed by 90 cm row spacing.

Effect of integrated nutrient management

Appraisal of data on leaf area shoot⁻¹ recorded at different crop growth stages revealed significant difference due to different integrated nutrient management practices during both the years of investigation.

At 150 DAP, the production of leaf area shoot⁻¹ due to application 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) (754.79 and 727.28 cm²) was found to at par with 100% RDF + enriched

compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (746.60 and 715.78 cm²), but significantly higher than 75% RDF+ FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (733.86 and 701.50 cm²), 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (724.95 and 694.32 cm²) and 100% RDF (F₁) (713.95 and 683.14 cm²) during 1st and 2nd year, respectively. However, the effect of F₃ and F₄, F₄ and F₅, F₅ and F₁ were found to be at par with each other. This might be due to better supply of nutrients for more leaf area development under the combined application of optimum dose of inorganic fertilizers along with organic source of nutrients.

At 180, 210 and 240 DAP, leaf area shoot⁻¹ recorded under the integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) (1538.67, 3078.34 and 4582.33 cm², respectively, during 2017-18 ; 1476.12, 3044.22 and 4426.45 cm², respectively, during 2018-19) was found to be at par with 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (1516.77, 3033.21 and 4500.64 cm², respectively, during 2017-18 ; 1442.34, 2966.98 and 4359.52 cm², respectively, during 2018-19), but found to be significantly higher than the application of 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (1500.92, 2960.18 and 4460.14 cm², respectively, during 2017-18; 1417.96, 2898.73 and 4312.07 cm², respectively, during 2018-19) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (1488.12, 2940.88 and 4431.67 cm², respectively, during 2017-18; 1414.63, 2870.32 and 4282.33 cm², respectively, during 2018-19). The lowest values (1416.34, 2846.52 and 4298.52 cm², respectively, during 2017-18; 1301.64, 2721.44 and 4054.76 cm², respectively, during 2018-19) were obtained under sole application of 100% RDF through inorganic fertilizers. Moreover, F₃ was found to be at par with F₄ and F₅ in effect at 180, 210 and 240 DAP during both the years of study.

At 300 DAP, significantly higher values of leaf area shoot⁻¹ (4182.69 and 4106.32 cm², during 2017-18 and 2018-19, respectively) were also registered under 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) which was found to be at par with 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (4143.26 and 4077.16 cm²) and 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (4104.83 and 4043.81 cm²) during 1st and 2nd year, respectively.

Moreover, F₃ was found to be at par with F₄ and F₅ in effect during both the years of study. All the above treatments produced significantly higher values as compared to 100% RDF (F₁) (3931.82 and 3758.22 cm²) during 2017-18 and 2018-19, respectively.

Throughout the crop growing period, the production of significantly higher leaf area shoot⁻¹ under the treatment F₂ might be due to application of organic nutrients like vermicompost, green manure along with biofertilizers and optimal dose of inorganic fertilizers that facilitated more uptake of nutrients to the crop for longer period of time which helped in maintaining more number of active leaves and as well as expansion of more leaf area. Besides this, the application of vermicompost played an important role in proper growth and development of plants due to presence of humic substances (Senesi *et al.*, 2007) and growth hormones like cytokinins and auxins (Krishnamoorthy and Vajrabhiah, 1986). Likewise, the other integrated nutrient management practices also increased the availability of nutrients to crop as compared to 100% RDF that resulted in more leaf area shoot⁻¹. Soomro *et al.* (2013) also reported maximum leaf area stalk⁻¹ due to integrated supply of 75% RDF along with FYM @ 20 t ha⁻¹ which was significantly higher as compared to 100% RDF. Similar result was also obtained by Ramesh *et al.* (2002).

Interaction effect

During both the years of investigation, the leaf area shoot⁻¹ recorded at different growth stages was remained unaffected due to interaction effect between crop establishment techniques and integrated nutrient management.

4.1.6 Leaf area index (LAI)

Data related to leaf area index (LAI) recorded at different growth stages *i.e.* at 120, 150, 180, 210, 240 and 300 DAP as affected by different crop establishment techniques and integrated nutrient management are presented in Table 4.6 and corresponding analyses of variance are appended in Appendix VI.

In the present investigation, the LAI increased with the advancement of crop growth and reached the maximum value at 240 DAP and thereafter, it started to decline towards maturity. The senescence of older leaves might be responsible for reduction in LAI at later stages of crop growth.

Effect of crop establishment techniques

The leaf area index calculated at different crop growth stages *viz.*, 120, 150, 180, 210, 240 and 300 DAP showed significant variation due to different crop establishment techniques during both the years. At 120 and 150 DAP, planting of bud chip seedling at 120 cm x 60 cm (M₃) registered significantly higher LAI (0.52 and 0.89, respectively, during 2017-18; 0.46 and 0.82, respectively, during, 2018-19) that was found to be at par with planting of bud chip seedling at 90 cm x 60 cm (M₂) (0.51 and 0.82, respectively, during 2017-18; 0.44 and 0.78, respectively, during 2018-19) but showed its superiority over the conventional method (M₁) (0.42 and 0.70, respectively, during 2017-18 ; 0.36 and 0.63, respectively, during 2018-19). The insignificant difference in LAI between M₃ and M₂ might be due to non-significant difference in total number of shoots and leaf area stalk⁻¹ at these particular stages during both the years.

But as the growth progressed, the LAI recorded at 180 and 210 DAP revealed significantly higher values (2.37 and 4.36, respectively, during 2017-18; 2.20 and 4.16, respectively, during 2018-19) under the planting of bud chip seedling at 120 cm x 60 cm (M₃) as compared to planting of bud chip seedling at 90 cm x 60 cm (M₂) (2.01 and 3.64, respectively, during 2017-18; 1.80 and 3.47 respectively, during 2018-19) and conventional method (M₁) (1.75 and 3.32, respectively, during 2017-18; 1.55 and 3.03, respectively, during 2018-19). At 180 DAP, both M₃ and M₂ were found to be significantly higher as compared to M₁ during both the years. But, at 210 DAP, the effect of M₁ and M₂ was found to be at par with each other during both the years of study.

At 240 DAP, planting of bud chip seedling at 120 cm x 60 cm (M₃) also exhibited the maximum LAI of 6.15 during 2017-18 and 5.65 during 2018-19 which was significantly higher than planting of bud chip seedling at 90 cm x 60 cm (M₂) (5.18 and 4.78) as well as conventional method of planting (M₁) (4.48 and 4.12) in 1st and 2nd year, respectively. At 300 DAP, although the planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded significantly higher LAI (4.46 and 4.36) as compared to conventional method (M₁) (3.82 and 3.64) but was at par with planting of bud chip seedling at 90 cm x 60 cm (M₂) (4.01 and 3.88) during 2017-18 and 2018-19, respectively. In both the stages of crop growth, M₁ and M₂ were at par in effect during both the years.

Table 4.6. Effect of crop establishment techniques and integrated nutrient management on leaf area index in sugarcane

Treatments	leaf area index (LAI)											
	2017-18						2018-19					
	Days after planting (DAP)						Days after planting (DAP)					
	120	150	180	210	240	300	120	150	180	210	240	300
Crop establishment technique (M)												
M ₁ : Conventional method	0.42	0.70	1.75	3.32	4.48	3.82	0.36	0.63	1.55	3.03	4.12	3.64
M ₂ : Bud chip seedling at 90 cm x 60 cm	0.51	0.82	2.01	3.64	5.18	4.01	0.44	0.78	1.80	3.47	4.78	3.88
M ₃ : Bud chip seedling at 120 cm x 60 cm	0.52	0.89	2.37	4.36	6.15	4.46	0.46	0.82	2.20	4.16	5.65	4.36
SEm±	0.02	0.02	0.06	0.13	0.18	0.13	0.02	0.02	0.05	0.13	0.18	0.13
CD (P=0.05)	0.08	0.09	0.23	0.52	0.70	0.51	0.08	0.06	0.22	0.50	0.71	0.49
Integrated nutrient management (F)												
F ₁ : 100% RDF	0.44	0.74	1.76	3.27	4.46	3.73	0.38	0.66	1.56	3.01	4.12	3.52
F ₂ : 100% RDF + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	0.51	0.83	2.21	4.04	5.64	4.25	0.44	0.78	2.01	3.84	5.18	4.14
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	0.50	0.83	2.14	3.96	5.60	4.20	0.43	0.77	1.94	3.77	5.11	4.10
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	0.48	0.81	2.07	3.84	5.44	4.16	0.42	0.76	1.88	3.62	5.01	4.06
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	0.48	0.79	2.04	3.75	5.23	4.13	0.42	0.75	1.86	3.56	4.86	3.98
SEm±	0.01	0.01	0.04	0.07	0.08	0.07	0.01	0.01	0.03	0.05	0.06	0.06
CD (P=0.05)	0.03	0.04	0.11	0.19	0.23	0.19	0.02	0.03	0.10	0.16	0.19	0.17
Interaction (M x F)												
SEm±	0.02	0.02	0.07	0.12	0.14	0.11	0.01	0.02	0.06	0.09	0.11	0.10
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: DAP: Days after planting ; RDF: Recommended dose of fertilizer; GM: Green manuring; VC: Vermicompost; EC: Enriched compost; BF: Biofertilizers; SEm±: Standard error of mean; CD: Critical difference, NS: Non significant

The variable LAI under different crop establishment techniques were ascribed due to variation in leaf area and number of shoots per unit area. The greater LAI due to planting of bud chip seedling at 120 cm x 60 cm (M₃) might be due to availability of proper spacing which resulted in development of more leaf area as well as shoots per unit area. Chilawal *et al.* (2018) also reported higher leaf area index due to planting of sugarcane bud chip seedling at 120 cm x 0.61 cm. Similar, findings were also reported by Khalid *et al.* (2015) and Nadeem *et al.* (2020).

Effect of integrated nutrient management

The leaf area index (LAI) recorded at different crop growth stages were significantly influenced by different integrated nutrient management practices during both the years. At 120 and 150 DAP, the treatments comprised of both organic and inorganic sources of nutrients were at par with each other and all of them were found superior to the application of 100% RDF (F₁) (0.44 and 0.74, respectively during 2017-18; 0.38 and 0.66, respectively, during 2018-19). However, significantly higher values were obtained due to the application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) (0.51 and 0.83, respectively during 2017-18; 0.44 and 0.78, respectively, during 2018-19). This might be due to insignificant difference in total shoot population as well as number of leaves plant⁻¹ during early stages of crop growth under different integrated nutrient management practices.

At 180 and 210 DAP, application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher LAI (2.21 and 4.04, respectively, during 2017-18 ; 2.01 and 3.84, respectively, during 2018-19) which was found to be at par with 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (2.14 and 3.96, respectively, during 2017-18; 1.94 and 3.77, respectively, during 2018-19) but found superior to the treatment comprised of 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (2.07 and 3.84, respectively, during 2017-18; 1.88 and 3.62, respectively, during 2018-19) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (2.04 and 3.75, respectively, during 2017-18; 1.86 and 3.56, respectively, during 2018-19). However, F₃, F₄ and F₅ were found to be at par in effect at 180 DAP during both the years. While, the effect of F₃ and F₄ as well as F₄ and F₅ were found to be at par with each other at

210 DAP during both the years. In both the periods, significantly lower values of 1.76 and 3.27, respectively, during 2017-18 and 1.56 and 3.01, respectively, during 2018-19 were obtained under the sole application of 100% RDF. The demands for more nutrients at these particular crop growing periods due to more shoot population per unit area might have resulted in significant difference in leaf area shoot⁻¹ which ultimately resulted in variation in LAI.

However, the maximum leaf area index of 5.64 during 2017-18 and 5.18 during 2018-19 was obtained at 240 DAP due to application 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) that was at par with the treatment receiving 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (5.60 and 5.11) and 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (5.44 and 5.01), but significantly higher than the application of 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (5.23 and 4.86) during 2017-18 and 2018-19, respectively. But all of them were found to be significantly higher in comparison to 100% RDF (F₁) (4.46, in 2017-18 and 4.12, in 2018-19). However, F₃ and F₄ as well as F₄ and F₅ did not differ from each other at 210 and 240 DAP during both the years.

During later stage of crop growth *i.e.* at 300 DAP, although the treatment receiving 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) (4.25 and 4.14) recorded significantly higher LAI as compared to 100% RDF (3.73 and 3.52), but found to be at par with all the treatments receiving integrated nutrient management *viz.*, 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (4.20 and 4.10), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (4.16 and 4.06) and 75% RDF + FYM @ 5 t ha⁻¹ + green manuring of cowpea + enriched compost @ 1 t ha⁻¹ (F₅) (4.13 and 3.98) in 2017-18 and 2018-19, respectively.

The above results clearly expressed that the integrated nutrient management practices recorded significantly higher leaf area index as compared to 100% RDF throughout the crop growing stages during both the years. Apart from inorganic fertilizers, the other sources of nutrients might have supplied more amount of nutrients to the crop resulting in more leaf area, number of leaves as well as shoots per unit area in comparison to 100% RDF. The production of higher leaf area as well as

more number of physiologically active leaves shoot⁻¹ recorded under the integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) led to significantly higher LAI throughout the crop growing period. In earlier findings, many researchers reported notable increase in leaf area index due to integration of both organic and inorganic sources of nutrients as compared to sole application of fertilizers (Swamy *et al.*, 1999; Soomro *et al.*, 2013 and Banerjee *et al.*, 2018).

Interaction effect

During both the years of investigation, the LAI recorded at different crop growth stages were remained unaffected due to interaction effect between crop establishment techniques and integrated nutrient management.

4.1.7 Leaf area duration (LAD) (days)

The data pertaining to leaf area duration (LAD) as influenced by crop establishment techniques and integrated nutrient management are presented in Table 4.7 and corresponding analyses of variance are appended in Appendix VII.

The degree and persistence of leaf area during a particular crop growth stage can be articulated by determining the LAD. In the present investigation, higher magnitudes of LAD being found during 210-270 DAP as compared to early stage of crop growth. Rai *et al.* (2017) also reported the similar findings.

Effect of crop establishment techniques

Data recorded at different crop growth periods at an interval of 60 days *i.e.* 90-150, 150-210 and 210-270 DAP showed significant difference in terms of leaf area duration (LAD) due to different crop established techniques in both the years.

A closure perusal of data on leaf area duration (LAD) revealed that in early stage of crop growth *i.e.* during 90-150 DAP; low magnitude of LAD was obtained under different crop establishment techniques, which ranged from 23.88 to 27.22 days and 20.22 to 25.52 days during 2017-18 and 2018-19, respectively. This might be due to production of lower magnitude of leaf area shoot⁻¹ during early stage of crop growth in all the crop establishment techniques. During this period, the highest LAD of 27.22 days in 2017-18 and 25.52 days in 2018-19 was recorded under the planting of bud chip seedling at 120 cm x 60 cm (M₃) which was found to be at par with planting of bud chip seedling at 90 cm x 60 cm (M₂) with 26.77 and 23.84 days for the

respective years. But, both of them recorded significantly higher LAD as compared to the conventional method (M_1) (23.88 and 20.22 days) during 2017-18 and 2018-19, respectively. The insignificant variation in LAD between M_3 and M_2 might be due to non-significant difference in leaf area shoot⁻¹ between them in early stage of crop growth during both the years.

Leaf area duration recorded during 150-210 DAP revealed that the values obtained under planting of bud chip seedling at 120 cm x 60 cm (M_3) (170.14 and 149.86 days) were significantly higher than planting of bud chip seedling at 90 cm x 60 cm (M_2) (141.22 and 126.64 days) as well as conventional method of planting (M_1) (123.24 and 111.44 days) during 2017-18 and 2018- 19, respectively. But, M_1 and M_2 were found to be at par in effect during both the years. Similar results were also obtained in case of LAD recorded during 210- 270 DAP in both the years of investigation. The planting of bud chip seedling at 120 cm x 60 cm (M_3) also recorded significantly higher LAD (287.74 and 284.27 days) as compared to the planting of bud chip seedling at 90 cm x 60 cm (M_2) (251.86 and 245.62 days) and conventional method of planting (M_1) (244.72 and 227.64 days) in 1st and 2nd year, respectively.

The significant variation in LAD might be due to significant difference observed in LAI under different crop establishment techniques during both the years. The wider planting and early establishment of plant under the planting of bud chip seedling at 120 cm x 60 cm (M_3) helped in development of more number of physiologically active leaves shoot⁻¹ as well as leaf surface area which increased the LAI and ultimately LAD. Nadeem *et al.* (2020) also reported higher LAD due to planting of sugarcane at 120 cm trenches than the other plant spacings.

Effect of integrated nutrient management

The leaf area duration (LAD) recorded at 60 days interval showed significant difference due to different integrated nutrient management practices during both the years. Irrespective of treatments, during the early growth stages *i.e.* 90-150 DAP, comparatively lesser LAD was recorded which gradually increased in subsequent crop growth stages *i.e.* during 150-210 and 210-270 DAP. This indicated high magnitude of leaf area and its persistence during 150-210 DAP and 210-270 DAP and reverse was found in early stages of crop growth. The slow crop canopy development at early stage of crop due to low temperature greatly reduced LAD in all the treatments.

Table 4.7. Effect of crop establishment techniques and integrated nutrient management on leaf area duration (LAD) in sugarcane

Treatments	Leaf area duration(days)					
	2017-18			2018-19		
	90 - 150 DAP	150 - 210 DAP	210 - 270 DAP	90 - 150 DAP	150 - 210 DAP	210 - 270 DAP
Crop establishment technique (M)						
M ₁ :Conventional method	23.88	123.24	244.72	20.22	111.44	227.64
M ₂ : Bud chip seedling at 90cm x 60 cm	26.77	141.22	251.86	23.84	126.64	245.62
M ₃ :Bud chip seedling at 120cm x 60 cm	27.22	170.14	287.74	25.52	149.86	284.27
SEm±	0.66	5.05	7.31	0.71	4.03	6.79
CD (P=0.05)	2.60	19.82	28.70	2.80	15.84	26.65
Integrated nutrient management (F)						
F ₁ : 100% RDF	24.62	120.01	225.18	21.67	114.06	218.67
F ₂ : 100% RDF + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	27.02	157.88	280.24	24.08	138.55	272.84
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	26.34	154.27	274.44	23.76	135.34	265.32
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	26.12	146.86	265.78	23.36	131.16	255.87
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	25.86	145.31	261.55	23.11	127.45	250.19
SEm±	0.34	1.98	2.90	0.30	1.42	2.59
CD (P=0.05)	0.98	5.77	8.47	0.87	4.17	7.56
Interaction (M x F)						
SEm±	0.58	3.42	5.02	0.51	3.43	4.48
CD (P=0.05)	NS	S	S	NS	S	S

Note: DAP: Days after planting ; RDF: Recommended dose of fertilizer; GM: Green manuring; VC: Vermicompost; EC: Enriched compost; BF: Biofertilizers; SEM±: Standard error of mean; CD: Critical difference , S: Significant NS: Non significant

Table 4.7.1. Interaction effect between the crop establishment techniques and integrated nutrient management on leaf area duration (LAD) at 150 -210 DAP

	2017-18					2018-19				
	F ₁	F ₂	F ₃	F ₄	F ₅	F ₁	F ₂	F ₃	F ₄	F ₅
M ₁ : Conventional method	107.03	133.23	126.60	124.54	124.78	102.73	117.27	114.35	112.57	110.31
M ₂ : Bud chip seedling at 90 cm x 60 cm	120.92	152.21	148.59	144.17	140.20	115.72	135.00	131.46	126.86	124.17
M ₃ : Bud chip seedling at 120 cm x 60 cm	132.09	188.19	187.63	171.87	170.94	123.75	163.39	160.21	154.06	147.88
			Sem±		CD(0.05)		Sem±		CD(0.05)	
M at the same level of F			3.42		9.99		2.43		5.02	
F at the same or different levels of M			5.49		16.03		4.11		8.47	

Note : F₁: 100% RDF; F₂: 100% RDF + green manuring of cowpea + vermicompost @ 1 t ha⁻¹ + biofertilizers @10 kg ha⁻¹; F₃: 100% RDF + green manuring of cowpea + enriched compost @ 1 t ha⁻¹ ; F₄: 75% RDF + FYM @ 5 t ha⁻¹ + green manuring of cowpea + vermicompost @ 1 t ha⁻¹ + biofertilizers @10 kg ha⁻¹ ; F₅: 75% RDF + FYM @ 5 t ha⁻¹ + green manuring of cowpea + enriched compost @ 1 t ha⁻¹

Table 4.7.2. Interaction effect between the crop establishment techniques and integrated nutrient management on total numbers of shoots plant⁻¹ at 210-270 DAP

	2017-18					2018-19				
	F ₁	F ₂	F ₃	F ₄	F ₅	F ₁	F ₂	F ₃	F ₄	F ₅
M ₁ : Conventional method	217.31	262.48	251.52	246.02	246.26	205.51	247.79	235.82	223.62	225.45
M ₂ : Bud chip seedling at 90 cm x 60 cm	226.57	267.52	261.57	254.82	248.85	222.95	262.05	252.67	245.65	244.78
M ₃ : Bud chip seedling at 120 cm x 60 cm	231.66	310.77	310.24	296.48	289.55	227.54	308.67	307.46	298.35	280.34
			Sem±		CD(0.05)		Sem±		CD(0.05)	
M at the same level of F			5.02		10.37		4.49		13.08	
F at the same or different levels of M			7.97		16.45		7.36		21.44	

Note : F₁: 100% RDF; F₂: 100% RDF + green manuring of cowpea + vermicompost @ 1 t ha⁻¹ + biofertilizers @10 kg ha⁻¹; F₃: 100% RDF + green manuring of cowpea + enriched compost @1 t ha⁻¹; F₄: 75% RDF + FYM @ 5 t ha⁻¹ + green manuring of cowpea + vermicompost @ 1 t ha⁻¹ + biofertilizers @10 kg ha⁻¹; F₅: 75% RDF + FYM @ 5 t ha⁻¹ + green manuring of cowpea + enriched compost @1t ha⁻¹

During 90-150 DAP, the integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded the highest LAD of 27.02 days during 2017-18 and 24.08 days during 2018-19 which was found to be at par with the application of 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (26.34 and 23.76 days) and 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (26.12 and 23.36 days), but found to be significantly higher as compared to 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (25.86 and 23.11 days) in 1st and 2nd year, respectively.

The maximum LAD (157.88 and 138.55 days) was also registered due to integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) during 150-210 DAP, which was found at par with 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (154.27 and 135.34 days), but superior to the treatments comprised of 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (146.86 and 131.16 days) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (145.31 and 127.45 days) during 2017-18 and 2018-19, respectively. However, F₄ and F₅ were found to be at par in effect during both the years of study.

In case of LAD recorded during 210-270 DAP, the treatment receiving 100% RDF + green manuring of cowpea + vermicompost @ 1 t ha⁻¹ + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher values (280.24 and 272.84 days, during 2017-18 and 2018-19, respectively) which was found to be at par with 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (274.44 and 265.32 days, during 2017-18 and 2018-19, respectively) and both of them were found superior to the treatments with 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (265.78 and 255.87 days) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (261.55 and 250.19 days) in 1st and 2nd year, respectively. However, during all the growth stages *i.e.* from 90-150, 150-210 and 210-270 DAP; the integrated nutrient management practices produced significantly higher LAD as compared to 100% RDF (24.62, 120.01 and 255.18 days, respectively, during 2017-18; 21.67 114.06 and 218.67 days, respectively, during 2018-19).

The significant variation in LAD under different treatments might be due to the variation in leaf area index due to different nutrient management practices. The production of significantly higher LAD under 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) might be due to higher nutrient uptake leading to increased leaf area, LAI and ultimately LAD. Keshavaiah (2012) also reported significant variation in LAD due to different integrated nutrient management in sugarcane. Similar finding was also reported by Kuri (2014).

Interaction effect

The leaf area duration (LAD) recorded at 150-210 and 210-270 DAP were significantly influenced by interaction effect between different crop establishment techniques and integrated nutrient management during both the years (Table 4.7.1 and 4.7.2).

Irrespective of crop establishment techniques, the treatments with integrated nutrient management significantly increased LAD over 100% RDF. Data revealed that among the treatment combinations, planting of bud chip seedling at 120 cm x 60 cm along with 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (M₃F₂) and planting of bud chip seedling at 120 cm x 60 cm and 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (M₃F₃) recorded significantly higher LAD (188.19 and 187.63 days, respectively, during 2017-18; 163.39 and 160.21 days, respectively, during 2018-19) as compared to all other treatment combinations during 150-210 DAP. Whereas, the minimum LAD was achieved under the conventional method in association with application of 100% RDF (M₁F₁) (107.03 and 102.73 days) during 1st and 2nd year, respectively.

A close perusal of data on LAD during 210 -270 DAP revealed that combined effect of planting of bud chip seedling at 120 cm x 60 cm along with 100 % RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (M₃F₂) recorded the maximum LAD (310.77 and 308.67 days) which was at par with planting of bud chip seedling at 120 cm x 60 cm and application of 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (M₃F₃) (310.24 and 307.46 days) and 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + biofertilizers @ 10 kg ha⁻¹ + green manuring of cowpea (M₃F₄) (296.48 and 298.35 days) during 2017-18 and 2018-19, respectively. The interaction between the conventional method and 100% RDF (M₁F₁) recorded the lowest LAD (217.31 and 205.51 days) during both the years.

The suitable planting technique along with proper nutrition helped in development of more leaf area index which ultimately increased the LAD.

4.1.8 Crop Growth Rate ($\text{g m}^{-2} \text{day}^{-1}$)

The mean values regarding crop growth rate (CGR) recorded at different growth stages at 60 days interval *i.e.* 90-150, 150-210, 210-270 and 330-390 DAP as influenced by crop establishment techniques and integrated nutrient management are presented in Table 4.8 and their corresponding analyses of variance are appended in Appendix VIII.

In the present investigation, the crop growth rates (CGR) of sugarcane increased linearly along with the increase in crop growth and reached the peak during 270-330 DAP and again declined towards maturity (Fig. 4.1a, 4.1b, 4.2a, 4.2b).

Effect of crop establishment techniques

An assessment of data pertaining to crop growth rate (CGR) presented in Table 4.8 showed significant differences in CGR due to different crop establishment techniques except during 90-150 and 330-390 DAP in 1st and 2nd year of experimentation. The less demand for all resources by the plants under reduced crop growth because of the low atmospheric temperature resulted insignificant difference during 90-150 DAP. While, the senescence of physiologically active leaves at later stage of crop growth might be responsible for insignificant difference during 330-390 DAP in both the years.

Crop growth rate recorded during 150-210 DAP revealed that planting of bud chip seedling at 120 cm x 60 cm (M_3) recorded the highest values ($12.52 \text{ g m}^{-2} \text{day}^{-1}$ in 1st year and 12.37 in 2nd year) which was significantly higher than the conventional method (M_1) ($10.54 \text{ g m}^{-2} \text{day}^{-1}$ in 1st year and $10.42 \text{ g m}^{-2} \text{day}^{-1}$ in 2nd year), but found to be at par with planting of bud chip seedling at 90 cm x 60 cm (M_2) ($11.18 \text{ g m}^{-2} \text{day}^{-1}$ in 1st year and $10.88 \text{ g m}^{-2} \text{day}^{-1}$ in 2nd year). However, no significant difference was observed between M_1 and M_2 during both the years.

Planting of bud chip seedling at 120 cm x 60 cm (M_3) revealed maximum CGR during 210-270 DAP (20.66 and $19.64 \text{ g m}^{-2} \text{day}^{-1}$) that was found to be significantly higher than planting of bud chip seedling at 90 cm x 60 cm (M_2) (17.42 and $16.82 \text{ g m}^{-2} \text{day}^{-1}$) and conventional method of planting (M_1) (16.58 and $15.76 \text{ g m}^{-2} \text{day}^{-1}$) during first and second year, respectively. However, M_1 and M_2 were at par in effect during both the years.

Table 4.8. Effect of crop establishment techniques and integrated nutrient management on crop growth rate in sugarcane

Treatments	Crop growth rate (g m ⁻² day ⁻¹)									
	2017-18					2018-19				
	90-150 DAP	150-210 DAP	210-270 DAP	270-330 DAP	330-390 DAP	90-150 DAP	150-210 DAP	210-270 DAP	270-330 DAP	330-390 DAP
Crop establishment technique (P)										
M ₁ : Conventional method	4.22	10.54	16.58	19.34	6.73	4.06	10.42	15.76	18.87	6.39
M ₂ : Bud chip seedling at 90 cm x 60 cm	4.38	11.18	17.42	20.48	6.86	4.43	10.88	16.82	20.33	6.48
M ₃ : Bud chip seedling at 120 cm x 60 cm	4.61	12.52	20.66	23.18	7.38	4.35	12.37	19.64	22.87	7.08
SEm±	0.11	0.35	0.75	0.73	0.22	0.12	0.38	0.67	0.65	0.24
CD (P=0.05)	NS	1.38	2.94	2.86	NS	NS	1.49	2.62	2.58	NS
Integrated nutrient management (F)										
F ₁ : 100% RDF	4.20	9.72	15.58	18.36	6.74	4.11	9.62	14.88	17.54	6.40
F ₂ : 100% RDF + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	4.60	12.16	19.33	22.10	7.13	4.42	11.92	18.63	21.88	6.82
F ₃ : 100% RDF + EC @ 1t ha ⁻¹ + GM	4.48	11.88	19.11	21.77	7.04	4.33	11.70	18.34	21.68	6.75
F ₄ : 75% RDF + FYM @ 5t ha ⁻¹ + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	4.42	11.64	18.74	21.43	7.03	4.26	11.53	17.86	21.37	6.65
F ₅ : 75% RDF + FYM @ 5t ha ⁻¹ + EC @ 1t ha ⁻¹ + GM	4.34	11.50	18.33	21.36	6.98	4.25	11.37	17.33	21.14	6.63
SEm±	0.09	0.13	0.33	0.36	0.09	0.08	0.13	0.36	0.27	0.10
CD (P=0.05)	NS	0.39	0.98	1.05	NS	NS	0.38	1.02	0.79	NS
Interaction (M x F)										
SEm±	0.16	0.23	0.58	0.62	0.16	0.14	0.22	0.61	0.50	0.17
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: DAP: Days after planting ; RDF: Recommended dose of fertilizer; GM: Green manuring; VC: Vermicompost; EC: Enriched compost; BF: Biofertilizers; SEM±: Standard error of mean; CD: Critical difference, NS: Non significant

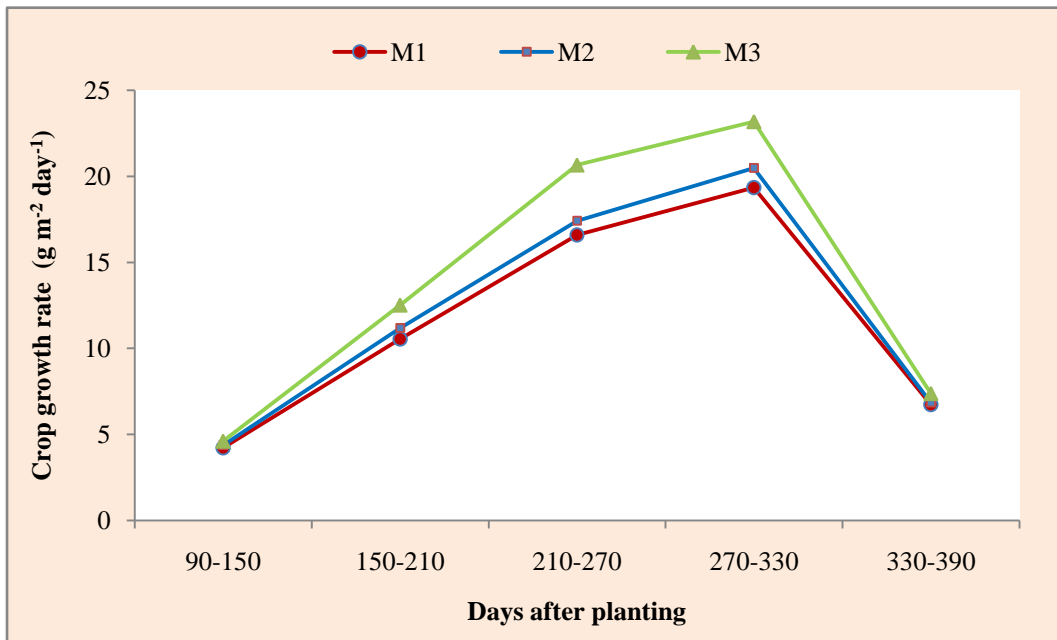


FIG. 4.1a. CGR AS AFFECTED BY CROP ESTABLISHMENT TECHNIQUES DURING 2017-18

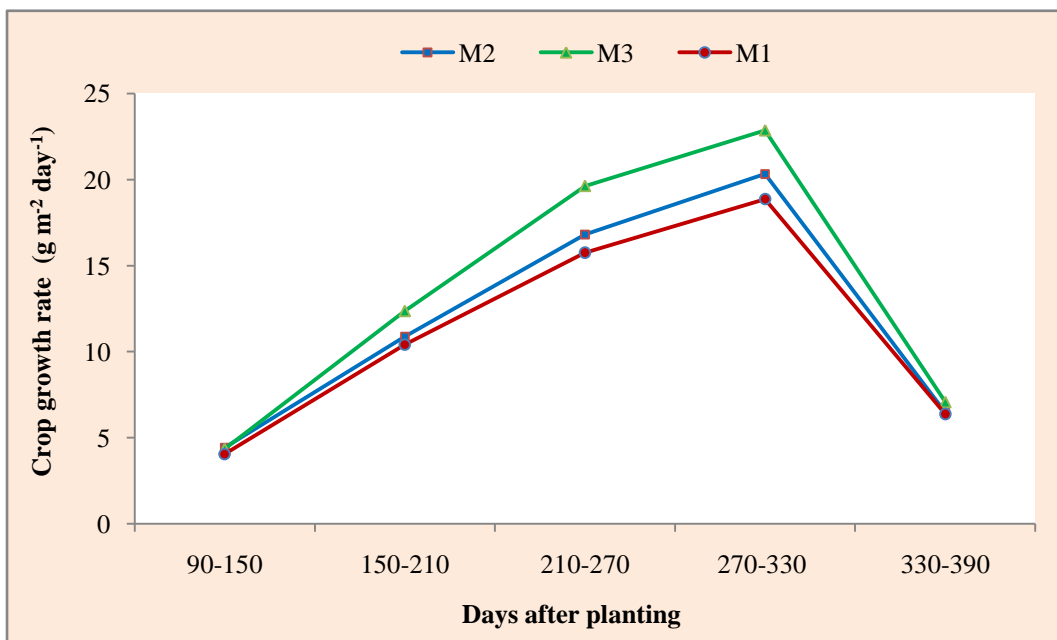


FIG. 4.1b. CGR AS AFFECTED BY CROP ESTABLISHMENT TECHNIQUES DURING 2018-19

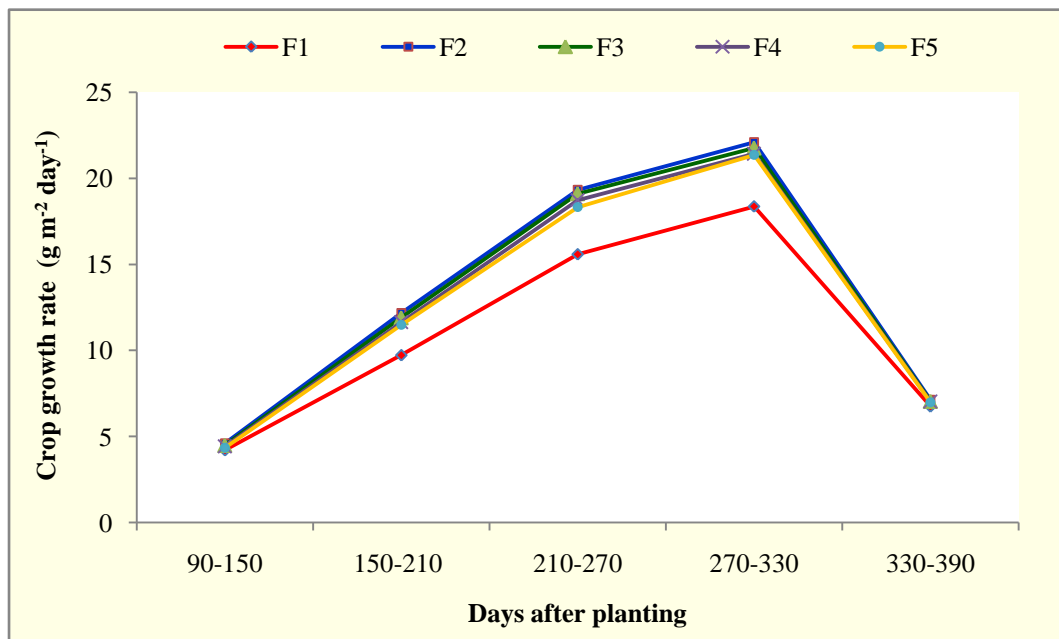


FIG. 4.2a. CGR AS AFFECTED BY INTEGRATED NUTRIENT MANAGEMENT DURING 2017-18

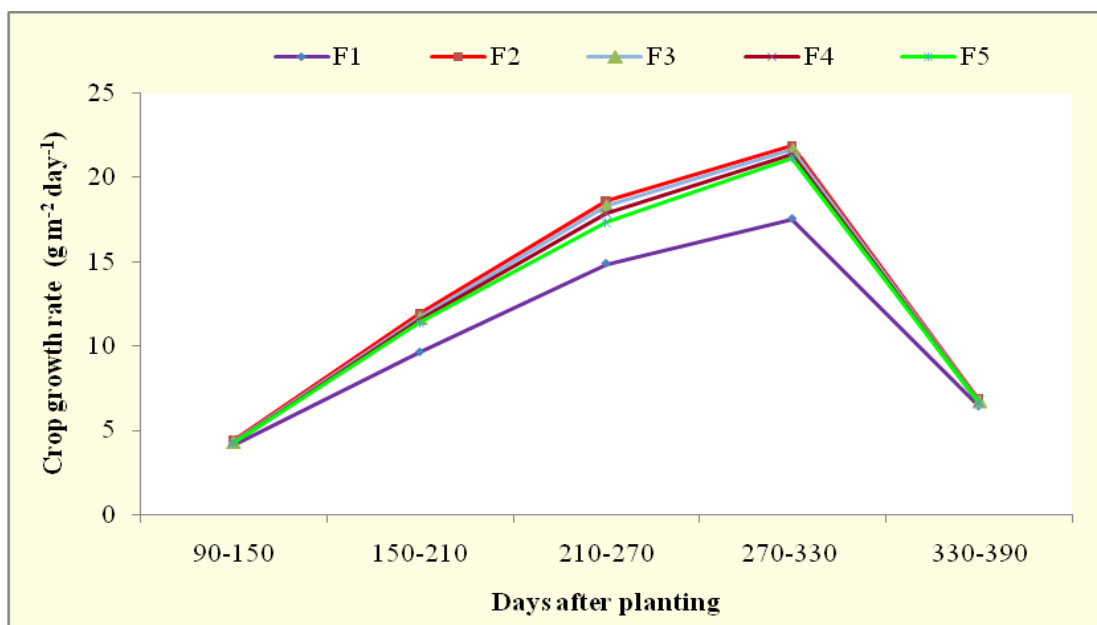


FIG. 4.2b. CGR AS AFFECTED BY INTEGRATED NUTRIENT MANAGEMENT DURING 2018-19

Similarly, CGR recorded during 270-330 DAP revealed maximum values under the planting of bud chip seedling at 120 cm x 60 cm (M₃) (23.18 and 22.87 g m⁻² day⁻¹) that was found to be at par with planting of bud chip seedling at 90 cm x 60 cm (M₂) (20.48 and 20.33 g m⁻² day⁻¹), but significantly superior to conventional method of planting (M₁) (19.34 and 18.87 gm⁻² day⁻¹) during 2017-18 and 2018-19, respectively.

The wider row spacing between the seedlings enabled the plants to harness more solar energy resulting in more crop growth under the planting of bud chip seedling at 120 cm x 60 cm. Besides this, the better root development in bud chip seedlings might have helped in absorption of more amount of nutrients to the plant resulting in better crop growth. While, the unavailability of certain nutrients to plants and mutual shading of many of the middle and lower leaves decreased the interception of light resulting in low photosynthetic efficiency. Hence, narrow planting under both the crop establishment techniques decreased the crop growth rate during both the years. While, the insignificant difference between the planting of bud chip seedling at 120 cm x 60 cm (M₃) and 90 cm x 60 cm (M₂) in later stage of crop growth might be due to decrease in number physiologically active leaves which reduced the CGR under both these techniques. Islam *et al.* (2008) stated that the wider row spacing helped in more interception of light even by the bottom leaves of sugarcane resulting in more CGR. Ghaffar *et al.* (2012) also reported higher crop growth rate of 12.68 gm⁻² day⁻¹ in 120 cm spaced trenches as compared to 90 cm. Similar findings were also reported by Rehman *et al.* (2013).

Effect of integrated nutrient management

Crop growth rate (CGR) calculated at different crop growth stages at 60 days interval *i.e.* 150-210, 210-270 and 270-330 DAP were significantly influenced by different integrated nutrient management practices except during 90-150 and 330-390 DAP during both the years.

Data furnished in Table 4.8 revealed that the crop growth rate (CGR) progressively increased with the increase in crop growth and reached the maximum during 270-330 DAP and again decreased during 330-390 DAP. Uddin *et al.* (1995) also reported that CGR continued to increase up to 330 DAP and declined afterwards. The integration of different organic sources of nutrients along with 100% RDF and 75% RDF fertilizers significantly increased the CGR than the sole application of 100%

RDF through inorganic source at 150-210, 210-270, 270-330 DAP during both the years.

Crop growth rate recorded during 150-210 DAP revealed that integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 Kg ha⁻¹ (F₂) registered significantly more values (12.16 and 11.92 gm⁻² day⁻¹) in comparison to the application 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (11.64 and 11.53 gm⁻² day⁻¹) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (11.50 and 11.37 gm⁻² day⁻¹) but found to be at par with 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (11.88 and 11.70 gm⁻² day⁻¹) in 1st and 2nd year, respectively. However, the effect of F₃, F₄ and F₅ were found to be at par with each other during both the years. All these treatments receiving integrated nutrient management practices were found to be significantly higher over the application of 100% RDF (9.72 and 9.62 gm⁻² day⁻¹) in 1st and 2nd year, respectively.

In case of crop growth rate recorded during 210-270 DAP, significantly higher values of 19.33 gm⁻² day⁻¹ during 2017-18 and 18.63 gm⁻² day⁻¹ during 2018-19 were obtained due to the integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) which was found at par with 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (19.11 and 18.34 gm⁻² day⁻¹) and 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (18.74 and 17.86 gm⁻² day⁻¹), but superior to the application of 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (18.33 and 17.33 gm⁻² day⁻¹) in 1st and 2nd year, respectively. Whereas, the lowest values were obtained under 100% RDF (F₁) (15.58 and 14.88 gm⁻² day⁻¹) during both the years.

The combined application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) also recorded the maximum CGR during 270-330 DAP (22.10 and 21.88 gm⁻² day⁻¹) followed by 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (21.77 and 21.68 gm⁻² day⁻¹), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (21.43 and 21.37 gm⁻² day⁻¹) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅)

(21.36 and 21.14 $\text{gm}^{-2} \text{day}^{-1}$) in 1st and 2nd year, respectively. All the above treatments were found to be at par with each other, but significantly higher than the CGR recorded at 100% RDF (F₁) (18.36 $\text{gm}^{-2} \text{day}^{-1}$ during 1st year and 17.54 $\text{gm}^{-2} \text{day}^{-1}$ during 2nd year).

The more availability of nutrients from different sources resulted in better crop growth under integrated supply of nutrients than the inorganic fertilizer alone. Besides this, the significant increase in CGR under the treatment F₂ might be due to the cumulative effect of different nutrient sources like vermicompost, green manuring, biofertilizers along with optimal dose of inorganic fertilizers that created favourable soil environment for more crop growth. In earlier finding, Keshavaiah (2012), also reported significantly higher CGR of 28.61 $\text{gm}^2 \text{day}^{-1}$ during 270 DAP to harvest due to integration of 50% N through pressmud + 50% NPK through fertilizer + biofertilizers than the 100% RDF through inorganic fertilizers .

Interaction effect

During both the years of investigation, the CGR recorded at different crop growth stages were remained unaffected due to interaction effect between crop establishment techniques and integrated nutrient management.

4.1.9 Relative growth rate (mg g day^{-1})

Relative growth rate (RGR) recorded at different crop growth stages at an interval of 60 days *i.e.* 90-150, 150-210, 210-270 and 270-330 DAP are presented in Table 4.9 and corresponding analyses of variance are appended in Appendix IX.

Data showed consistently decreasing trend in RGR with the advancement of crop growth and the highest being found at the initial stage of crop growth in both the years of investigation (Fig. 4.3a, 4.3b, 4.4a and 4.4b). Uddin *et al.* (1995) also reported decreasing trend in case of RGR.

Effect of crop establishment techniques

Relative growth rate (RGR) was not significantly influenced by different crop established techniques in both the years. Yet, the planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded comparatively higher RGR than planting of bud chip seedling at 90 cm x 60 cm (M₂) and conventional planting (M₁) during all the crop growth stages in both the years. During 90-150 DAP, the maximum value of 10.14 $\text{mg g}^{-1} \text{day}^{-1}$ in 2017-18 and 9.42 $\text{mg g}^{-1} \text{day}^{-1}$ in 2018-19 was obtained under the planting of

Table 4.9. Effect of crop establishment technique and integrated nutrient management on relative growth rate in sugarcane

Treatments	Relative growth rate (mg g ⁻¹ day ⁻¹)							
	2017-18				2018-19			
	Days after planting (DAP)				Days after planting (DAP)			
	90-150	150-210	210-270	270-330	90-150	150-210	210-270	270-330
Crop establishment technique (P)								
M ₁ : Conventional method	9.68	6.21	5.11	4.63	9.18	5.74	4.96	4.42
M ₂ : Bud chip seedling at 90 cm x 60 cm	9.95	6.48	5.32	4.79	9.38	6.08	5.14	4.53
M ₃ : Bud chip seedling at 120 cm x 60 cm	10.14	6.72	5.57	5.05	9.42	6.34	5.35	4.84
SEm±	0.13	0.16	0.10	0.20	0.14	0.22	0.27	0.23
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Integrated nutrient management								
F ₁ : 100% RDF	9.72	6.11	4.95	4.56	9.21	5.68	4.72	4.32
F ₂ : 100% RDF + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	10.04	6.71	5.52	4.95	9.46	6.30	5.34	4.74
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	9.91	6.65	5.45	4.92	9.37	6.15	5.28	4.68
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	9.88	6.47	5.41	4.86	9.32	6.09	5.23	4.65
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	9.85	6.41	5.36	4.81	9.26	6.05	5.18	4.58
SEm±	0.05	0.09	0.08	0.07	0.05	0.08	0.09	0.08
CD (P=0.05)	0.16	0.25	0.24	0.22	0.15	0.23	0.26	0.24
Interaction (M x F)								
SEm±	0.09	0.15	0.15	0.13	0.09	0.14	0.16	0.14
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Note: DAP: Days after planting; RDF: Recommended dose of fertilizer; GM: Green manuring; VC: Vermicompost; EC: Enriched compost; BF: Biofertilizers; SEm±: Standard error of mean; CD: Critical difference

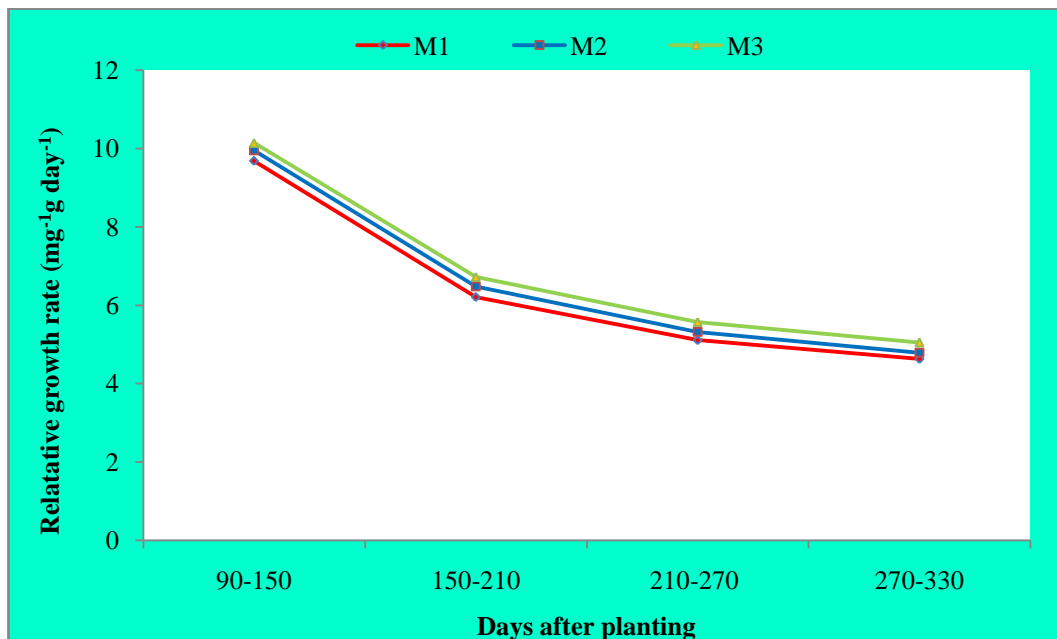


FIG. 4.3a. RGR AS AFFECTED BY DIFFERENT CROP ESTABLISHMENT TECHNIQUES DURING 2017-18

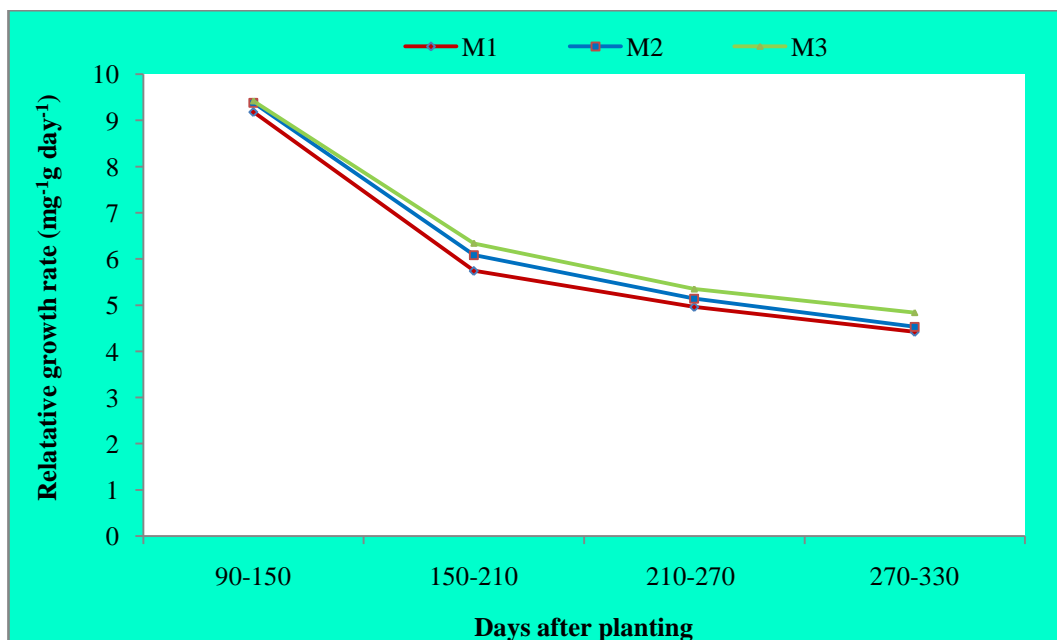


FIG. 4.3b. RGR AS AFFECTED BY DIFFERENT CROP ESTABLISHMENT TECHNIQUES DURING 2018-19

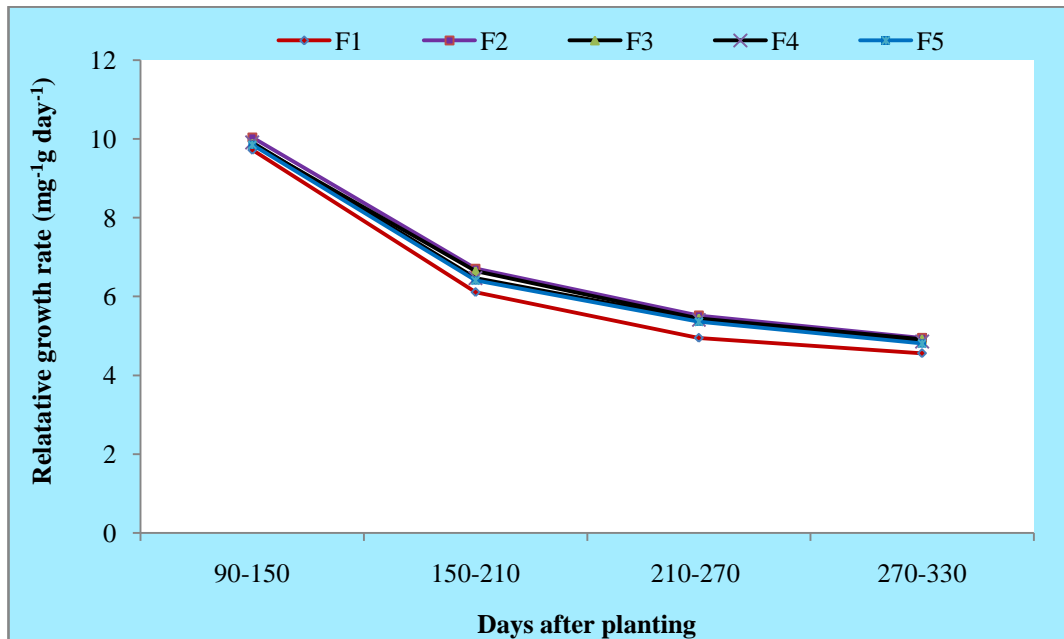


FIG. 4.4a. RGR AS AFFECTED BY INTEGRATED NUTRIENT MANAGEMENT DURING 2017-18

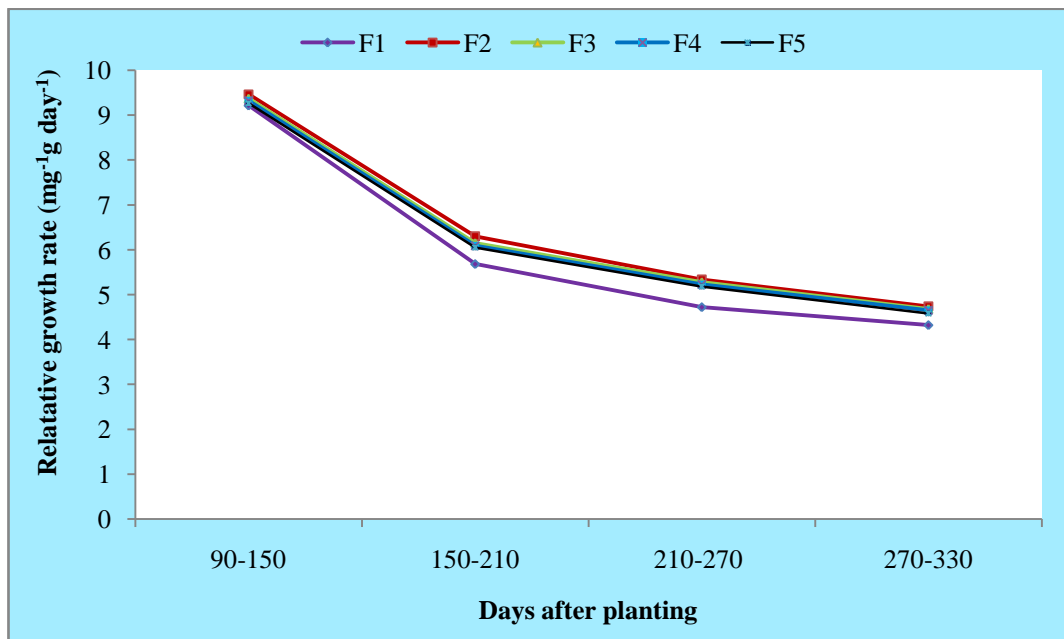


FIG. 4.4b. RGR AS AFFECTED BY INTEGRATED NUTRIENT MANAGEMENT DURING 2018-19

bud chip seedling at 120 cm x 60 cm (M_3) which greatly reduced up to $5.05 \text{ mg g}^{-1} \text{ day}^{-1}$ in 2017-18 and $4.84 \text{ mg g}^{-1} \text{ day}^{-1}$ in 2018-19 during 270-330 DAP. Similar trend was also observed in case of both M_1 and M_2 during both the years.

Effect of integrated nutrient management

Application of different integrated nutrient management practices significantly affected the relative growth rate (RGR) recorded at different crop growth stages *i.e.* 90-150, 150-210, 210-270 and 270-330 DAP during both the years.

The application of 100% RDF + vermicompost @ 1 t ha^{-1} + green manuring of cowpea + biofertilizers @ 10 kg ha^{-1} (F_2) registered the maximum RGR during 90-150 DAP (10.04 and $9.46 \text{ mg g}^{-1} \text{ day}^{-1}$) which was found to be at par with 100% RDF + enriched compost @ 1 t ha^{-1} + green manuring of cowpea (F_3) (9.91 and $9.37 \text{ mg g}^{-1} \text{ day}^{-1}$) and 75% RDF + FYM @ 5 t ha^{-1} + vermicompost @ 1 t ha^{-1} + green manuring of cowpea + biofertilizers @ 10 kg ha^{-1} (F_4) (9.88 and $9.32 \text{ mg g}^{-1} \text{ day}^{-1}$), but found to be significantly higher as compared to 100% RDF (F_1) (9.72 and $9.21 \text{ mg g}^{-1} \text{ day}^{-1}$) and 75% RDF + FYM @ 5 t ha^{-1} + enriched compost @ 1 t ha^{-1} + green manuring of cowpea (F_5) (9.85 and $9.26 \text{ mg g}^{-1} \text{ day}^{-1}$) during 2017-18 and 2018-19, respectively. Besides this, F_3 was found to be at par with F_4 and F_5 but superior to F_1 during both the years. However, no significant difference was observed among F_4 , F_5 and F_1 during both the years of investigation. The variation in RGR among the treatments might be due to variation in dry matter production. The addition of optimum dose of inorganic fertilizers along with organic sources like FYM, green manuring, vermicompost as well as biofertilizers might have created better soil environment for release of more nutrients from the soil that resulted in more dry matter production.

Relative growth rate (RGR) recorded during 150-210 DAP also revealed significantly higher values under 100% RDF + vermicompost @ 1 t ha^{-1} + green manuring of cowpea + biofertilizers @ 10 kg ha^{-1} (F_2) (6.71 and $6.30 \text{ mg g}^{-1} \text{ day}^{-1}$) which was at par with the application of 100% RDF + enriched compost @ 1 t ha^{-1} + green manuring of cowpea (F_3) (6.65 and $6.15 \text{ mg g}^{-1} \text{ day}^{-1}$) and 75% RDF + FYM @ 5 t ha^{-1} + vermicompost @ 1 t ha^{-1} + green manuring of cowpea + biofertilizers @ 10 kg ha^{-1} (F_4) (6.47 and $6.09 \text{ mg g}^{-1} \text{ day}^{-1}$) during 2017-18 and 2018-19, respectively. However, F_3 , F_4 and F_5 were found at par with each other during both the years. At this stage, all the treatments comprised of integrated nutrient management recorded significantly higher values than 100% RDF (F_1).

Relative growth rate (RGR) recorded during 210-270 DAP and 270-330 DAP revealed that all the integrated nutrient management practices found to be at par with each other except 100% RDF, but comparatively higher values were obtained under the integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) (5.52 and 4.95 mg g⁻¹ day⁻¹, respectively, during 2017-18; 5.34 and 4.74 mg g⁻¹ day⁻¹, , respectively, during 2018-19) followed by 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (5.45 and 4.92, respectively, during 2017-18; 5.28 and 4.68 mg g⁻¹ day⁻¹, respectively, during 2018-19), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (5.41 and 4.86 mg g⁻¹ day⁻¹, respectively, during 2017-18; 5.23 and 4.65 mg g⁻¹ day⁻¹, respectively, during 2018-19) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (5.36 and 4.81, respectively, during 2017-18; 5.18 and 4.58 mg g⁻¹ day⁻¹, respectively, during 2018-19). The significant improvement under integrated supply of nutrients over the sole inorganic fertilizers at later stage of crop growth might be due to optimum and timely supply of nutrients as per the need of crop, which ultimately increased both growth parameters as well as dry matter production of crop. This finding is corroborating with findings of Ajay *et al.* (2005) and Singh and Agrawal (2001).

Interaction effect

The interaction effect between the crop establishment techniques and integrated nutrient management did not show any significant variation in RGR during both the years of investigations.

4.1.10 N - related parameters

The N related parameters such as total chlorophyll content (mg g⁻¹), green seeker NDVI (Normalized Difference Vegetation Index) value and crop canopy temperature as affected by crop establishment techniques and integrated nutrient management are presented in Table 4.10 and corresponding analyses of variance are appended in Appendix X.

The quantifications of chlorophyll is considered as an important parameter to have an idea about the quantum of pigments involved in light absorption and energy transfer during the photochemical process of photosynthesis. The high magnitude of chlorophyll content in plant leaves depicts the high N level in leaves (Basai *et al.*, 2018). Similarly, the green seeker NDVI value depicts the plant health or

Table 4.10. Effect of crop establishment techniques and integrated nutrient management on chlorophyll content, green seeker NDVI and crop canopy temperature in sugarcane

Treatments	Total Chlorophyll content (mg g ⁻¹)				Green seeker NDVI		Crop canopy temperature (°C)	
	240 DAP		330 DAP		330 DAP		330 DAP	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Crop establishment technique (M)								
M ₁ : Conventional method	1.75	1.70	1.53	1.51	0.367	0.358	36.81	37.04
M ₂ : Bud chip seedling at 90 cm x 60 cm	1.78	1.75	1.54	1.52	0.381	0.376	36.29	36.55
M ₃ : Bud chip seedling at 120 cm x 60 cm	1.84	1.82	1.57	1.54	0.388	0.386	35.84	35.85
SEm±	0.06	0.06	0.04	0.05	0.013	0.006	0.73	0.69
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Integrated nutrient management practices (F)								
F ₁ : 100% RDF	1.63	1.61	1.44	1.40	0.352	0.345	37.66	38.02
F ₂ : 100% RDF + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	1.85	1.83	1.60	1.59	0.391	0.388	35.71	35.58
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	1.84	1.82	1.58	1.58	0.386	0.383	35.87	35.88
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	1.82	1.78	1.56	1.53	0.381	0.379	36.14	36.32
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	1.81	1.77	1.56	1.53	0.380	0.373	36.18	36.60
SEm±	0.03	0.02	0.03	0.03	0.006	0.007	0.32	0.36
CD (P=0.05)	0.08	0.07	0.08	0.08	0.016	0.020	0.92	1.04
Interaction (M x F)								
SEm±	0.05	0.04	0.05	0.05	0.009	0.012	0.55	0.61
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Note: DAP: Days after planting; RDF: Recommended dose of fertilizer; GM: Green manuring; VC: Vermicompost; EC: Enriched compost; BF: Biofertilizers; SE_m±: Standard error of mean; CD: Critical difference, NS: Non significant

status of vegetation depending upon the value ranging from 0.00 to 0.99. Generally, healthier plants produce higher NDVI values (Tadesse *et al.*, 2015) and it also positively related to leaf chlorophyll content. The leaf nutrient content also determines the crop canopy temperature.

4.1.10.1 Total chlorophyll content (mg g^{-1})

Effect of crop establishment techniques

Estimation of total chlorophyll content at 240 and 330 DAP remained unaffected due to different crop establishment techniques during both the years. However, irrespective of crop establishment techniques, the chlorophyll content recorded at 240 DAP was comparatively higher as compared to 330 DAP during both the years.

In both the stages of crop growth *i.e.* at 240 and 330 DAP; comparatively more chlorophyll content (1.84 and 1.57 mg g^{-1} , respectively, during 2017-18; 1.82 and 1.54 mg g^{-1} , respectively, during 2018-19) was obtained under the planting of bud chip seedling at $120 \text{ cm} \times 60 \text{ cm}$ (M_3) as compared to planting of bud chip seedling at $90 \text{ cm} \times 60 \text{ cm}$ (M_2) (1.78 and 1.54 mg g^{-1} , respectively, during 2017-18; 1.75 and 1.52 mg g^{-1} , respectively, during 2018-19) and conventional method of planting (M_1) (1.75 and 1.53 mg g^{-1} , respectively, during 2017-18; 1.70 and 1.51 mg g^{-1} , respectively, during 2018-19). Chilawal *et al.* (2018) also reported that the leaf chlorophyll content was not significantly influenced by planting of sugarcane under different row plant spacing.

Effect of integrated nutrient management

Data pertaining to total chlorophyll content recorded at 240 and 330 DAP showed significant variation due to different integrated nutrient management practices in both the years. At both stages of crop growth, all the treatments receiving integrated nutrient management were at par with each other except 100% RDF during both the years. However, comparatively higher values were obtained due to the combined application of 100% RDF + vermicompost @ 1 t ha^{-1} + green manuring of cowpea + biofertilizers @ 10 kg ha^{-1} (F_2) (1.85 and 1.60 mg g^{-1} , respectively, during 2017-18; 1.83 and 1.59 mg g^{-1} , respectively, during 2018-19) followed by the application of 100% RDF + enriched compost @ 1 t ha^{-1} + green manuring of cowpea (F_3) (1.84 and 1.58 mg g^{-1} , respectively, during 2017-18; 1.82 and 1.58 mg g^{-1} , respectively, during 2018-19), 75% RDF+ FYM @ 5 t ha^{-1} + vermicompost @ 1 t ha^{-1} + green manuring of cowpea + biofertilizers @ 10 kg ha^{-1} (F_4) (1.82 and 1.56 mg g^{-1} ,

respectively, during 2017-18; 1.78 and 1.53 mg g⁻¹, respectively, during 2018-19) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (1.81 and 1.56 mg g⁻¹, respectively, during 2017-18; 1.77 and 1.53 mg g⁻¹, respectively, during 2018-19). While, the application of 100% RDF (F₁) registered the lowest values (1.63 and 1.44 mg g⁻¹, respectively, during 2017-18; 1.61 and 1.40 mg g⁻¹, respectively, during 2018-19) in both the stages of crop growth.

The above results clearly expressed that all the treatments recorded more amount of total chlorophyll content at 240 DAP as compared to 330 DAP. This indicated the presence of more nutrient content in leaf tissue during early growth stage as compared to later crop growth stages. The leaf nutrient content especially the nitrogen might have helped in synthesis of more chlorophyll under the integrated nutrient management than the 100% RDF through inorganic fertilizers. Similarly, Banerjee *et al.* (2018) also noted significant increase in total chlorophyll content due to integration of FYM, biofertilizers in combination with inorganic fertilizers over sole inorganic fertilizers. These results corroborate the earlier results reported by Nazirkar and Kamthe (2012) and Bokhtiar *et al.* (2015).

Interaction effect

The total chlorophyll content remained unaffected due to interaction effect between crop establishment techniques and integrated nutrient management during both the years.

4.1.10.2 Green seeker NDVI (Normalized difference vegetation index)

Effect of crop establishment techniques

The green seeker NDVI value recorded at 330 DAP did not significantly differ due to different crop establishment techniques during both the years of investigation. Though non-significant, planting of bud chip seedling at 120 cm x 60 cm (M₃) produced comparatively higher green seeker NDVI values (0.388 and 0.386) as compared to planting of bud chip seedling at 90 cm x 60 cm (M₂) (0.381 and 0.376) and conventional method of planting (M₁) (0.367 and 0.358) during 2017-18 and 2018-19, respectively.

Effect of integrated nutrient management

The integrated nutrient management practices significantly influenced the green seeker NDVI recorded at 330 DAP during both the years of investigation. The

treatments comprising of both organic and inorganic sources of nutrients produced significantly higher values than the 100% RDF through inorganic fertilizers, but at par with each other during both the years. However, the application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) produced the maximum values (0.391 and 0.388) followed by the application of 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (0.386 and 0.383), 75% RDF+ FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (0.381 and 0.379) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (0.380 and 0.373) in 1st and 2nd year, respectively. The lowest value was obtained under 100% RDF (F₁) (0.352 in 2017-18 and 0.345 in 2018-19).

The higher values obtained under the integrated supply of both organic and inorganic sources denoted the development of healthier plant as compared to plants grown under sole inorganic fertilizers. The presence of high amount of chlorophyll and leaf nitrogen content might have increased the green seeker NDVI value under integrated nutrient management practices as compared to application of inorganic fertilizers alone. Tadesse *et al.* (2015) also reported higher NDVI values with more availability of nitrogen under the higher rates of nitrogenous fertilizer.

Interaction effect

The green seeker NDVI remained unaffected due to interaction effect between crop establishment techniques and integrated nutrient management during both the years.

4.1.10.3 Crop canopy temperature (°C)

Effect of crop establishment technique

The different crop establishment techniques did not show any significant variation in crop canopy temperature recorded at 330 DAP during both the years. The crop canopy temperature ranged from 35.84 °C to 36.81°C during 2017-18 and 35.85°C to 37.04°C during 2018-19 under different crop establishment techniques. However, comparatively lesser crop canopy temperature were recorded under the planting of bud chip seedling at 120 cm x 60 cm (M₃) and 90 cm x 60 cm (M₂) (35.84 and 36.29°C, respectively, during 2017-18; 35.85 and 36.55°C, respectively, during 2017-18) as compared to conventional method (M₁) (36.81 and 37.04°C) during 1st and 2nd year, respectively. The availability of more nutrients to the crop helped in reduction of crop

canopy temperature. From the above discussion, it was cleared that plants grown through bud chip seedlings were healthier than the plants raised under conventional method.

Integrated nutrient management

The integrated nutrient management significantly influenced the crop canopy temperature recorded at 330 DAP during both the years. All the treatment receiving integrated nutrient management practices significantly lowered the crop canopy temperature as compared to sole inorganic fertilizers, but all of them were at par with each others during both the years. The highest crop canopy temperature of 37.66°C during 2017-18 and 38.02°C during 2018-19 were obtained under 100% RDF (F₁), while the minimum values were registered due to application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) (35.71 and 35.58°C) followed by 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (35.87 and 35.88 °C), 75% RDF+ FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (36.14 and 36.32°C) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (36.18 and 36.60°C) in 1st and 2nd year, respectively.

The significant rise in crop canopy temperature under 100% RDF might be due to inadequate or insufficient supply of nutrients to the crop at that particular stage of crop growth. While, prolong and adequate supply of nutrients under the integrated nutrient management as per need of the crop might have helped in significant reduction in crop canopy temperature. Although, no significant difference was observed among the treatments comprising of organic sources of nutrients along with 100 and 75% RDF, but the effect was found to be more pronounced under integration with 100% RDF as compared to 75% RDF.

Interaction effect

The interaction between crop establishment techniques and integrated nutrient management could not bring any significant effect on crop canopy temperature (°C) during both the years.

4.1.11 Root length (cm) and root dry weight plant⁻¹ (g)

Data pertaining to root length and root dry weight plant⁻¹ as influenced by crop establishment techniques and integrated nutrient management are presented in Table 4.11 and corresponding analyses of variance are appended in Appendix XI.

4.1.11.1 Root length (cm)

Effect of crop establishment techniques

The root length recorded at 120, 150 and 180 DAP was significantly influenced by different crop establishment techniques during both the years. The root length progressively increased and reached the maximum value at 180 DAP during both the years. At 120 DAP, significantly higher root length of 17.48 cm during 2017-18 and 14.83 cm during 2018-19 was obtained under planting of bud chip seedling at 120 cm x 60 cm (M₃) which was at par with the planting of bud chip seedling at 90 cm x 60 cm (M₂) (16.08 cm during 2017-18 and 13.44 cm during 2018-19) and both of them were superior to the conventional method (M₁) (9.51 cm during 2017-18 and 8.83 cm during 2018-19).

At 150 and 180 DAP also, the planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded significantly higher root length (20.56 and 24.38 cm, respectively, during 2017-18; 19.64 and 24.08 cm, respectively, during 2018-19) which was significantly higher as compared to the planting of bud chip seedling at 90 cm x 60 cm (M₂) (17.02 and 20.44 cm, respectively, during 2017-18; 16.58 and 19.82 cm, respectively, during 2018-19) and conventional method (M₁) (13.18 and 17.68 cm, respectively, during 2017-18; 12.62 and 15.64 cm, respectively, during 2018-19). However, both M₂ and M₃ were superior to the conventional method (M₁) during both the years.

The bud chip seedling raised through utmost care in nursery helped in development of proper root growth as well as optimum availability of resources to the individual plant due to adequate spacing maintained among the seedlings in the main field might have helped in more proliferation of root as compared to conventional method. While, in later stage, the competition amongst the seedlings due to accommodation of more plants per unit area under the closer planting of bud chip seedling reduced the root growth. On the other hand, wider planting of bud chip seedling allowed more space for better proliferation of root.

Table 4.11. Effect of crop establishment techniques and integrated nutrient management on root length and root dry weight of sugarcane

Treatments	Root length (cm)						Root dry weight (g plant ⁻¹)					
	2017-18			2018-19			2017-18			2018-19		
	120 DAP	150 DAP	180 DAP	120 DAP	150 DAP	180 DAP	120 DAP	150 DAP	180 DAP	120 DAP	150 DAP	180 DAP
Crop establishment techniques (M)												
M ₁ : Conventional method	9.51	13.18	17.68	8.83	12.62	15.64	8.92	12.53	16.00	8.22	9.46	14.53
M ₂ : Bud chip seedling at 90 cm x 60 cm	16.08	17.02	20.44	13.44	16.58	19.82	17.88	20.56	27.18	16.15	18.99	25.16
M ₃ : Bud chip seedling at 120 cm x 60 cm	17.48	20.56	24.38	14.83	19.64	24.08	19.83	23.58	33.80	19.68	22.21	31.74
SEm±	0.39	0.53	0.48	0.38	0.43	0.61	0.55	1.07	0.91	0.71	1.03	0.92
CD (P=0.05)	1.52	2.10	1.18	1.49	1.68	2.39	2.14	4.17	3.58	2.78	4.07	3.64
Integrated nutrient management (F)												
F ₁ : 100% RDF	12.58	14.12	17.18	10.42	14.84	16.32	13.33	15.46	21.97	12.48	13.57	21.22
F ₂ : 100% RDF + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	15.17	18.07	22.43	13.04	16.87	21.40	16.60	20.27	27.22	15.62	18.28	25.11
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	15.02	18.04	22.16	12.84	16.62	21.14	16.35	20.20	27.08	15.44	18.06	25.04
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	14.68	17.26	21.88	12.73	16.56	20.22	15.84	19.41	26.07	15.04	17.34	23.88
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	14.46	17.11	20.54	12.64	16.50	19.11	15.61	19.08	25.98	14.83	17.18	23.83
SEm±	0.29	0.36	0.43	0.26	0.19	0.46	0.30	0.39	0.43	0.22	0.34	0.46
CD (P=0.05)	0.84	1.05	1.25	0.77	0.54	1.34	0.88	1.12	1.26	0.64	1.00	1.32
Interaction (M x F)												
SEm±	0.50	0.62	0.74	0.45	0.32	0.79	0.52	0.94	0.75	0.38	0.59	0.78
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: DAP: Days after planting; RDF: Recommended dose of fertilizer; GM: Green manuring; VC: Vermicompost; EC: Enriched compost; BF: Biofertilizers; SEm±: Standard error of mean; CD: Critical difference, NS: Non significant

Effect of integrated nutrient management

The different integrated nutrient management practices significantly influenced the root length recorded at 120, 150 and 180 DAP during both the years. At 120 and 150 DAP, all the treatments comprising of both organic and inorganic sources of nutrient significantly increased the root length as compared to 100% RDF, but all of them were at par with each other during both the years. However, integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) produced comparatively higher values (15.17 and 18.07 cm, respectively, during 2017-18; 13.04 and 16.87 cm, respectively, during 2018-19) followed by the application of 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (15.02 and 18.04 cm, respectively, during 2017-18; 12.84 and 16.62 cm, respectively, during 2018-19), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (14.68 and 17.26 cm, respectively during 2017-18; 12.73 and 16.56 cm, respectively 2018-19) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (14.46 and 17.11 cm, respectively during 2017-18; 12.64 and 16.50 cm, during 2018-19).

At 180 DAP, the treatment receiving the integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) also recorded significantly higher root length (22.43 and 21.40 cm) as compared to 100% RDF (F₁) (17.18 and 16.32 cm) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (20.54 and 19.11 cm) but at par with 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (22.16 and 21.14 cm) and 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (21.88 and 20.22 cm) during 1st and 2nd year, respectively.

Interaction effect

During both the years, the root length recorded at different crop growth stages remained unaffected due to interaction effect between crop establishment techniques and integrated nutrient management.

4.1.11.2 Root dry weight (g plant⁻¹)

Effect of crop establishment techniques

The different crop establishment techniques showed significant variation in root dry weight recorded at 120, 150 and 180 DAP during both the years.

The data pertaining to root dry weight recorded at 120 and 150 DAP revealed significantly more root dry weight (19.83 and 23.58 g, respectively, during 2017-18 ; 19.68 and 22.21 g, respectively, during 2018-19) under the planting of bud chip seedling at 120 cm x 60 cm (M₃) which were at par with planting of bud chip seedling at 90 cm x 60 cm (M₂) (17.88 and 20.56 g, respectively, during 2017-18; 16.15 and 18.99 g, respectively, during 2018-19) but significantly greater than conventional method (M₁) (8.92 and 12.53 g, respectively, during 2017-18; 8.22 and 9.46 g, respectively, during 2018-19). The significant increase in root dry weight under bud chip seedling technique over conventional method might be due to more root penetration in early stage of crop growth as well as proper root establishment in nursery that might have helped in absorption of more amount of water and nutrients for development of more root biomass. While, in case of conventional method, planting of setts directly in main field restricted the proliferation of roots due to competition for nutrients and resources.

At 180 DAP, planting of bud chip seedling at 120 cm x 60 cm (M₃) also recorded significantly higher root dry weight (33.80 and 31.74 g) than the planting of bud chip seedling at 90 cm x 60 cm (M₂) (27.18 and 25.16 g) as well as conventional method (M₁) (16.00 and 14.53 g) during 1st and 2nd year, respectively. However, M₂ also produced significantly more root dry weight than M₁ in all recorded period during both the years.

The proper allocation of all resources under wider spacing probably helped in more proliferation of roots, while, the narrow planting might have allowed the proliferation of roots up to a particular growing period, thereafter, competition for resources and space reduced the root growth.

Effect of integrated nutrient management

Significant differences in root dry weight was recorded due to different integrated nutrient management practices in both the years. Data recorded at 120, 150 and 180 DAP revealed that all the treatments comprised of integrated nutrient

management practices registered significantly more root dry weight as compared to 100% RDF (F₁) in both the years.

At 120 and 150 DAP, application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea+ biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher root dry weight (16.60 and 20.27 g, respectively, during 2017-18; 15.62 and 18.28 g, respectively, during 2018-19) which was at par with the integrated supply of 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (16.35 and 20.20 g, respectively, during 2017-18; 15.44 and 18.06 g, respectively, during 2018-19) and 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea+ biofertilizers @ 10 kg ha⁻¹ (F₄) (15.84 and 19.41g, respectively, during 2017-18; 15.04 and 17.34 g, respectively, during 2018-19), but superior to the application of 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (15.61 and 19.08 g, respectively, during 2017-18; 14.83 and 17.18 g, respectively, during 2018-19). During both the stages of crop growth, the lowest values were obtained under 100% RDF (F₁) (13.33 and 15.46 g, respectively, during 2017-18; 12.48 and 13.57 g, respectively, during 2018-19). However, F₃, F₄ and F₅ were at par in effect at 120 and 150 DAP during both the years.

At 180 DAP, no significant difference was observed among all the treatments receiving integrated nutrient management except 100% RDF during both the years. However, comparatively higher values of 27.22 g during 2017-18 and 25.11g during 2018-19 were obtained due to the integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) followed by treatments receiving 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃), (27.08 and 25.04 g) and 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (26.07 and 23.88 g) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (25.98 and 23.83 g) during 1st and 2nd year, respectively. All the above treatments were found significantly higher than the application of 100% RDF (F₁) (21.97 g in 1st year and 21.22 g in 2nd year).

In all the crop growing periods, the application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) registered the highest values against the lowest values obtained under 100% RDF (F₁) during both the years. The addition of vermicompost, biofertilizers and other organic nutrient sources along with optimal dose of inorganic fertilizers might have created

more congenial soil environment for development of roots. Moreover, the improvement of soil environment due to addition of organic sources of nutrients, biofertilizers helped in more proliferation of roots. On the other hand, the more competition for nutrients under 100% RDF restricted the development of roots.

Interaction effect

The interaction effect between the crop establishment techniques and integrated nutrient management was found non-significant in root dry weight during both the years.

4.1.12 Dry weight of above ground biomass shoot⁻¹ (g) (stem, leaves and total)

The biomass production is an important parameter that ultimately determined the yield of sugarcane. In the present investigation, the above ground biomass productions by different plant parts mainly stem and leaves portion as well as total biomass production shoot⁻¹ on dry weight basis as influenced by crop establishment techniques and integrated nutrient management are presented in Table 4.12, Fig. 4.5a, 4.5.b, 4.6.a and 4.6.b corresponding analyses of variance are appended in Appendix XII.

4.1.12.1 Dry weight of above ground biomass shoot⁻¹ (stem)

Effect of crop establishment techniques

The dry matter production by stem recorded at 210 and 270 DAP was significantly influenced by different crop establishment techniques. In the both the stages of crop growth *i.e.* at 210 and 270 DAP, planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded significantly higher values (26.44 and 104.72 g, respectively, during 2017-18; 24.67 and 102.72 g, respectively, during 2018-19) as compared to the planting of bud chip seedling at 90 cm x 60 cm (M₂) (19.88 and 90.86 g, respectively, during 2017-18; 20.26 and 88.16 g, respectively, during 2018-19) as well as conventional method of planting (M₁) (17.64 and 87.62 g, respectively, during 2017-18; 16.81 and 84.81 g, respectively, during 2018-19).

The variation in stem dry matter production under different crop establishment techniques might be due to the variation in rate of photosynthesis and translocation of photosynthates. Marchiori *et al.* (2010) stated that more interception and distribution of light in the canopy of sugarcane caused an increase in photosynthesis and vegetative growth through increased tillers, leaf area, and ultimately stem biomass accumulation.

Table 4.12. Effect of crop establishment techniques and integrated nutrient management on dry weight of above ground biomass in sugarcane

Treatments	Dry weight of above ground biomass shoot ⁻¹ (g)											
	2017-18						2018-19					
	210DAP			270DAP			210DAP			270DAP		
	Stem	Leaves	Total	Stem	Leaves	Total	Stem	Leaves	Total	Stem	Leaves	Total
Crop establishment technique (M)												
M ₁ : Conventional method	17.64	51.33	68.97	87.62	74.08	161.70	16.81	45.86	62.67	84.81	72.54	157.35
M ₂ : Bud chip seedling at 90 cm x 60 cm	19.88	52.57	72.45	90.86	77.68	168.54	20.26	46.71	66.97	88.16	76.40	164.56
M ₃ : Bud chip seedling at 120 cm x 60 cm	26.44	55.32	81.76	104.72	80.24	184.96	24.67	50.17	74.84	102.72	78.64	181.36
SEm±	0.72	1.28	2.16	2.77	1.98	3.17	0.67	1.57	1.90	1.98	2.20	4.26
CD (P=0.05)	2.84	NS	8.50	10.88	NS	12.46	2.66	NS	7.48	7.75	NS	16.71
Integrated nutrient management (F)												
F ₁ : 100% RDF	17.66	50.36	68.02	81.07	72.03	153.10	18.23	44.95	63.18	77.08	72.07	149.15
F ₂ : 100% RDF + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	23.44	55.08	78.52	100.18	80.53	180.71	22.40	49.26	71.66	98.22	78.35	176.57
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	23.08	54.52	77.60	98.80	78.98	177.78	21.82	48.38	70.20	97.33	77.77	175.11
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	21.54	53.64	75.18	95.78	77.82	173.61	20.33	47.84	68.17	93.56	75.67	169.23
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	20.88	53.48	74.36	95.43	77.50	172.93	20.18	47.58	67.76	93.28	75.43	168.71
SEm±	0.32	0.94	0.93	0.85	0.97	1.37	0.29	0.62	0.87	1.13	0.92	1.85
CD (P=0.05)	0.92	2.77	2.72	2.50	2.84	4.01	0.85	1.82	2.54	3.31	2.69	5.39
Interaction (M x F)												
SEm±	0.55	1.64	1.62	1.50	1.69	2.38	0.50	1.08	1.52	1.96	1.59	3.20
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: DAP: Days after planting ; RDF: Recommended dose of fertilizer; GM: Green manuring; VC: Vermicompost; EC: Enriched compost; BF: Biofertilizers; SEm± : Standard error of mean; CD: Critical difference, NS: Non significant

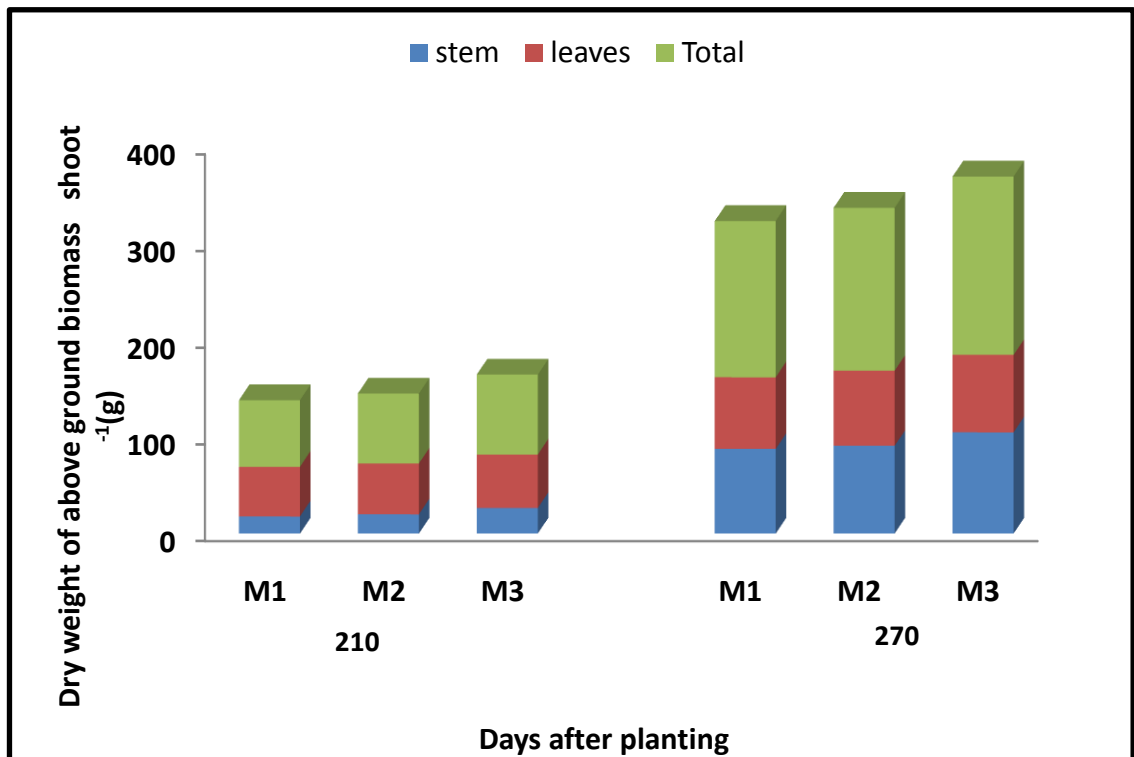


Fig 4.5a. ABOVE GROUND BIOMASS SHOOT⁻¹ AS AFFECTED BY CROP ESTABLISHMENT TECHNIQUES DURING 2017-18

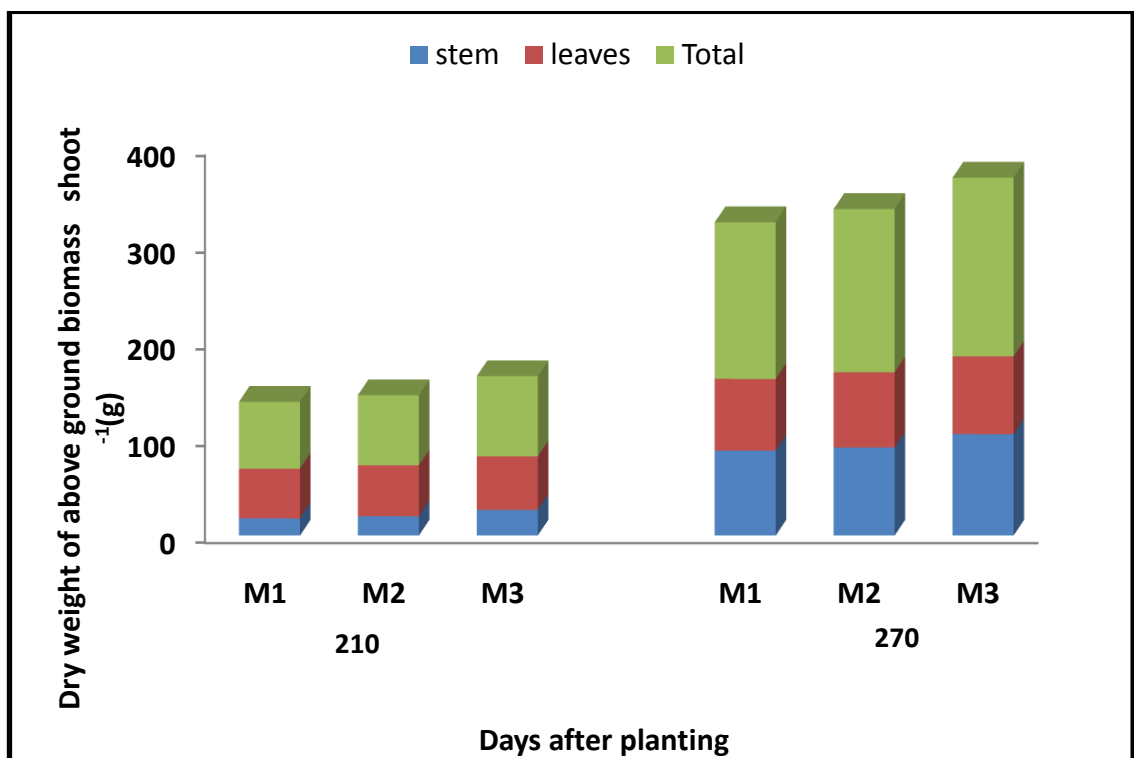


Fig 4.5(b): ABOVE GROUND BIOMASS SHOOT⁻¹ AS AFFECTED BY CROP ESTABLISHMENT TECHNIQUES DURING 2018-19

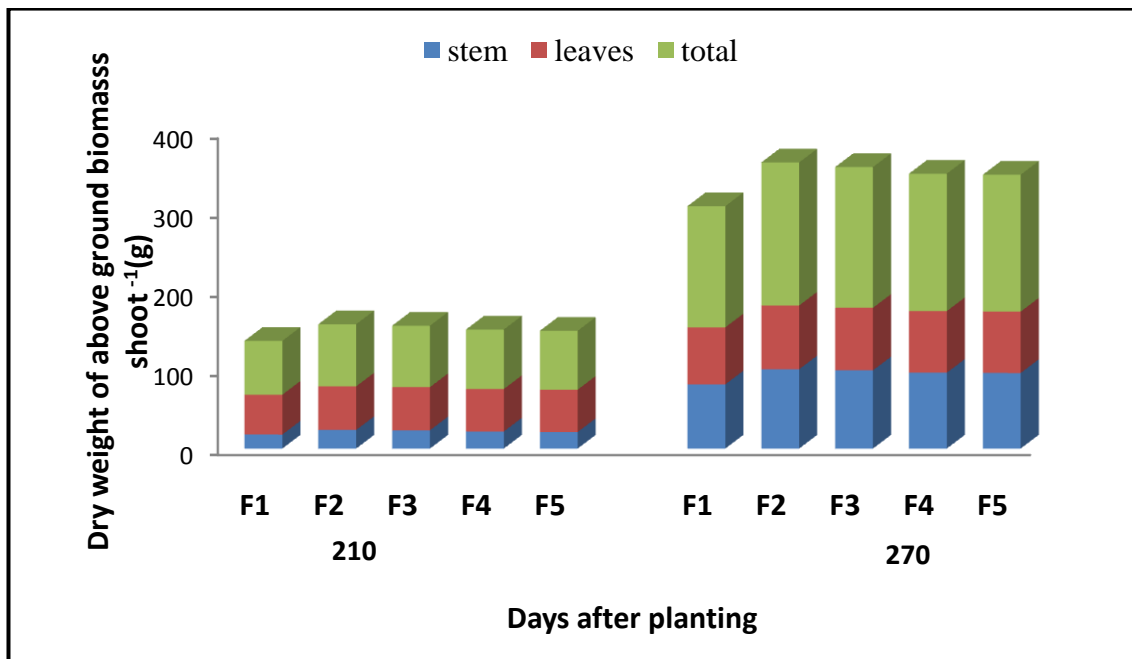


Fig 4.6(a): ABOVE GROUND BIOMASS SHOOT⁻¹ AS AFFECTED BY INTEGRATED NUTRIENT MANAGEMENT DURING 2017-18

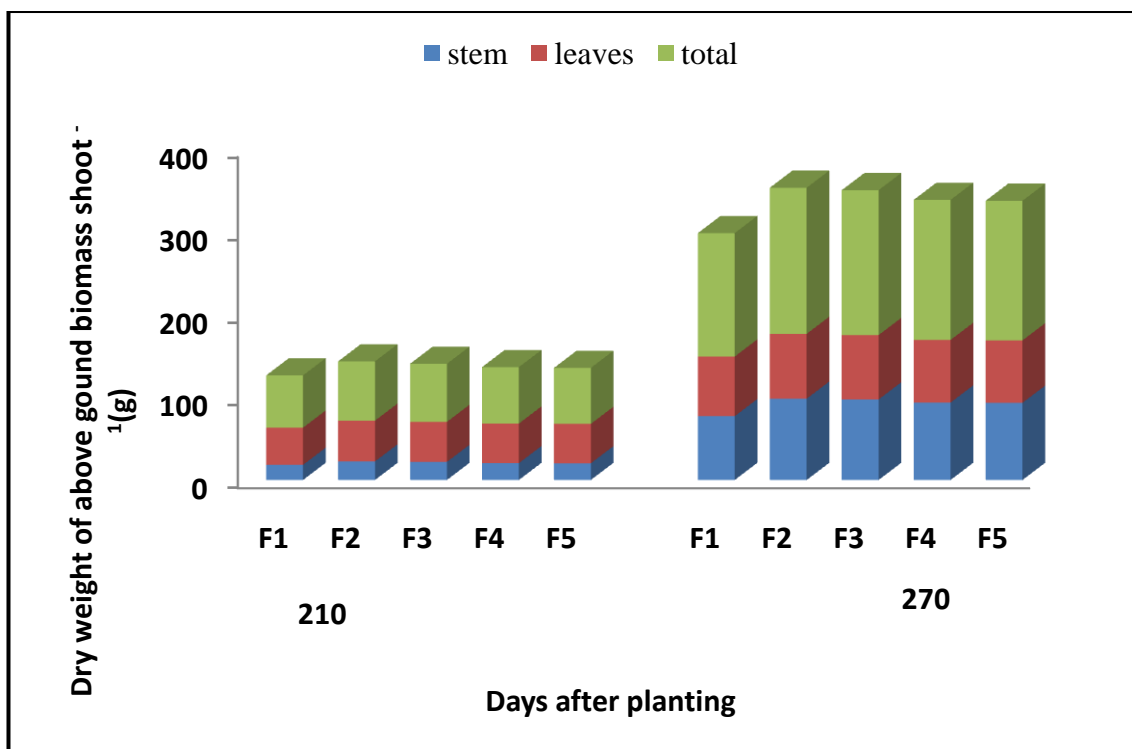


Fig 4.6(b): ABOVE GROUND BIOMASS SHOOT⁻¹ AS AFFECTED BY INTEGRATED NUTRIENT MANAGEMENT DURING 2018-19

Effect of integrated nutrient management

Different integrated nutrient management practices significantly influenced the dry matter production by stems recorded at 210 and 270 DAP in both the years. Results revealed that dry matters produced by stem at 210 DAP were comparatively less as compared to leaves, but, with the progress of crop growth *i.e.* at 270 DAP; the dry biomass production by stem increased progressively than the leaves.

In both the stages crop growth, the integrated application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher dry matters production by stem (23.44 and 100.18 g, respectively, during 2017-18; 22.40 and 98.22 g, respectively, during 2018-19) which was at par with the integrated application 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (23.08 and 98.80 g, respectively, during 2017-18; 21.82 and 97.33 g, respectively, during 2018-19), but superior to the treatment receiving 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (21.54 and 95.78, respectively, during 2017-18; 20.33 and 93.56 g, respectively, during 2018-19) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (20.88 and 95.43 g, respectively, during 2017-18; 20.18 and 93.28 g, respectively, during 2018-19). But, no significant variation was observed between F₄ and F₅ during both the years. The more amount of nutrients supplied through optimal dose of inorganic fertilizers along with different organic sources facilitated the crop for more leaf area expansion as well as accumulation of more assimilates into the stem.

4.1.12.2 Dry weight of above ground biomass shoot⁻¹ (leaves)

Effect of crop establishment techniques

No significant difference was observed in terms of dry matter production by leaves recorded at 210 and 270 DAP due to different crop establishment techniques during both the years.

However, in both the stages of crop growth *i.e.* 210 and 270 DAP, planting of bud chip seedling at 120 cm x 60 cm spacing (M₃) recorded comparatively higher values (55.32 and 80.24 g, respectively, during 2017-18; 50.17 and 78.64 g, respectively, during 2018-19) as compared to planting of bud chip seedling at 90 cm x 60 cm (M₂) (52.57 and 77.68 g, respectively, during 2017-18; 46.71 and 76.40 g, respectively, during 2018-19) and conventional method of planting (M₁) (51.33 and

74.08 g, respectively, during 2017-18; 45.86 and 72.54 g, respectively, during 2018-19). At 210 DAP, the dry matters produced by leaves was comparatively higher than the stem and the reverse was found at 270 DAP under all the crop establishment techniques. This might be due to diversion of more nutrients for development of economic part in later stage of crop growth. Felipe *et al.* (2018) also reported that the dry matter accumulation by leaves in early stage of crop growth was more as compared to dry matter produced by stem, but reverse was found in later stage of crop growth.

Effect of integrated nutrient management

The dry weight of above ground biomass (leaves) recorded at 210 and 270 DAP were significantly differed due to different integrated nutrient management practices during both the years. All treatments comprised of integrated nutrient management practices registered significantly higher dry biomass production by leaves as compared to 100% RDF at 210 and 270 DAP during both the years. At 210 DAP, other than 100% RDF (F₁), all the integrated nutrient management treatments were at par with each other but with the progress in crop growth significant variations were observed among them. However, significantly higher values of 55.08 g during 2017-18 and 49.26 g during 2018-19 was obtained with the application of 100% RDF + vermicompost @ 1 t ha⁻¹ + biofertilizers @ 10 kg ha⁻¹ + green manuring of cowpea (F₂) against the lowest values produced by 100% RDF (F₁) (50.36 and 44.95 g during 2017- and 2018-19, respectively).

At 270 DAP, the application of 100% RDF + green manuring of cowpea + vermicompost @ 1 t ha⁻¹ + biofertilizers @ 10 kg ha⁻¹ (F₂) also recorded significantly higher values (80.53 g in 2017-18 and 78.35 g in 2018-19) as compared to 100% RDF (F₁) (72.03 g in 2017-18 and 72.07 g in 2018-19) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (77.50 g in 2017-18 and 75.43 g in 2018-19) but at par with 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (78.98 g in 2017-18 and 77.77 g in 2018-19) and 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (77.82 g in 2017-18 and 75.67 g in 2018-19). However, F₃, F₄ and F₅ were at par in effect during both the years of experimentation.

The adequate supply of nutrients under F₂ helped in maintaining more number of physiologically active leaves as well as expansion of leaf area that resulted in more dry matter production by leaves. Besides this, the production of more leaf area

shoot⁻¹ as well numbers of leaves under the integrated nutrient management might have resulted in variation in dry biomass produced by leaves shoot⁻¹. Kuri (2014) also reported significant variations in dry matter production by both stem and leaves due to different integrated nutrient management practices.

Interaction effect

During both the years of investigations, the dry weight of both stem and leaves recorded at different crop growth stages were remained unaffected due to interaction between crop establishment techniques and integrated nutrient management.

4.1.12.2 Total dry weight shoot⁻¹ (g)

The data on total dry weight production shoot⁻¹ in both the years of investigation are presented in Table 4.12 and corresponding analyses of variance are appended in Appendix XII.

Effect of crop establishment techniques

The total dry weight production shoot⁻¹ recorded at 210 and 270 DAP were significantly influenced by different crop establishment techniques during both the years. Irrespective of crop establishment techniques, the total dry weight production shoot⁻¹ progressively increased with the advancement of crop growth and reached maximum values at 270 DAP.

In both the stage of crop growth, planting of bud chip seedling at 120 cm x 60 cm (M₃) registered significantly higher values (81.76 and 184.96 g, respectively, during 2017-18; 74.84 g and 181.36 g, respectively, during 2018-19) than the planting of bud chip seedling at 90 cm x 60 cm (M₂) (72.45 and 168.54 g, respectively, during 2017-18; 66.97 and 164.56 g, respectively, during 2018-19) as well as conventional method of planting (M₁) (68.97 and 161.70 g, respectively, during 2017-18; 62.67 and 157.35 g, respectively, during 2018-19). However, M₁ and M₂ did not differ from each other during both the stages of crop growth.

The significant variation in total dry matter production shoot⁻¹ might be due to variation in dry matter production by both stem and leaves. Cheema *et al.* (2002) also reported more dry matter production under the wider planting as compared to narrow spacing in sugarcane.

Effect of integrated nutrient management

The different nutrient management practices significantly affected the total dry weight production shoot⁻¹ recorded at 210 DAP and 270 DAP in both the years.

All the integrated nutrient management treatments recorded significantly higher total dry weight production shoot⁻¹ as compared to 100% RDF. During both the stages of crop growth, application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) registered the maximum values (78.52 and 180.71 g, respectively, during 2017-18 ; 71.66 and 176.57 g, respectively, during 2018-19) which was at par with the treatment comprised of 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (77.60 and 177.78 g, respectively 2017-18; 70.20 and 175.11 g, respectively during 2018-19), but found superior to the application 75% RDF+ FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (75.18 and 173.61 g, respectively 2017-18 ; 68.37 and 169.23 g, respectively during 2018-19) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @1 t ha⁻¹ + green manuring of cowpea (F₅) (74.36 and 172.93 g, respectively, 2017-18 ; 67.76 g and 168.71 g, respectively, during 2018-19). However, F₂ and F₃ as well as F₄ and F₅ were at par in effect at 270 DAP during both the years. Similar trend was also observed in case of total dry weight production recorded at 210 DAP during 2017-18, but F₃, F₄ and F₅ were at par in effect during 2018-19. The significant variation in total dry biomass production shoot⁻¹ was due to the variation in dry matter by both leaves and stem.

Results clearly expressed that integration of different sources of nutrients along with 100% RDF *i.e.* F₂ and F₃ recorded higher values as compared to integration with 75% RDF *i.e.* F₄ and F₅ during both the stages of crop growth. This might be due to more nutrients released under optimal dose of inorganic fertilizers along with organic sources of nutrients during both the stages. Banerjee *et al.* (2018) also reported that the integration of inorganic fertilizers along with FYM, biofertilizers produced significantly more dry matter production than the inorganic fertilizers alone.

Interaction effect

No significant difference on total dry weight production shoot⁻¹ was recorded due to due to interaction effect between crop establishment techniques and integrated nutrient management during both the years.

4.2 Yield attributes and yield

The data in respect of yield attributing characters such as length of millable cane, diameter of millable cane, number of millable cane, average weight of millable cane, length of internodes, number of internodes cane⁻¹ as well as yield of sugarcane as affected by crop establishment techniques and integrated nutrient management are presented in Table 4.13 and 4.14 and corresponding analyses of variance is appended in Appendix XIII and XIV.

4.2.1 Length of millable cane (cm)

The data pertaining to length of millable cane recorded at harvest are presented in Table 4.13 and corresponding analyses of variance are appended in Appendix XIII.

Effect of crop establishment techniques

The length of millable cane recorded during harvesting was significantly influenced by different crop establishment techniques in both years of experimentation. The planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded significantly higher length of millable cane (298.30 and 285.52 cm) as compared to the planting of bud chip seedling at 90 cm x 60 cm (M₂) (272.11 and 261.70 cm) as well as conventional method (M₁) (267.91 cm and 255.81 cm) during 2017-18 and 2018-19, respectively. But, the effect of M₁ and M₂ were at par with each other during both the years. The variation in length of millable cane was due to significant variation in plant height under different crop establishment techniques. Ghaffar *et al.* (2012) also reported more cane length under 120 cm trench spacing (232.2 cm) as compared 90 cm spacing (202.2 cm). The increase in cane length under bud chip technology as compared to conventional method was also reported by Samant (2017).

Effect of integrated nutrient managements

In both the years, length of millable cane was significantly influenced by different integrated nutrient management practices. All the integrated nutrient management treatments significantly increased the length of millable cane as compared to 100% RDF through inorganic fertilizers in both years of experimentation. The application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher length of millable cane (286.39 and 275.53 cm) which was at par with all the treatments comprising of

integrated nutrient management viz., 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (283.94 and 273.26 cm), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (281.50 and 269.58 cm) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (279.72 and 268.75 cm) during 2017-18 and 2018-19, respectively. Whereas, significantly lower values of 264.51 cm during 2017-18 and 251.25 cm during 2018-19 were obtained under the treatment receiving 100% RDF (F₁). Kumar *et al.* (2019) also reported that the integrated application of FYM @ 10 t ha⁻¹ and bio-fertilizers along with 100% RDF significantly increased the length of millable cane as compared to 100% RDF. A considerable increase in cane length due to the addition of FYM @ 10 t ha⁻¹ along with 100% RDF as compared to 100% RDF alone was also reported by Kumar *et al.* (2017). Similar results were also reported by Baneerje *et al.* (2018).

4.2.2 Diameter of millable cane (cm)

The data on diameter of millable cane recorded at harvest of sugarcane are presented in Table 4.13 and corresponding analyses of variance are appended in Appendix XIII.

Effect of crop establishment techniques

The different crop establishment techniques failed to exert any significant variation in diameter of the millable cane in both the years. But, planting of bud chip seedling at 120 cm x 60 cm (M₃) slightly increased the diameter of the cane (2.74 and 2.68 cm) as compared to planting of bud chip seedling at 90 cm x 60 cm (M₂) (2.72 and 2.66 cm) as well as conventional method of planting (M₁) (2.72 and 2.65 cm) during both the years. The better utilization of all resources due to planting of bud chip seedling at 120 cm x 60 cm (M₃) resulted in more cane diameter.

Effect of integrated nutrient management

The diameter of millable cane was not significantly influenced by integrated nutrient management in both the years. However, the integrated supply of both organic and inorganic sources of nutrients slightly increased the diameter of millable cane than 100% RDF in both the years. Among the INM treatments, 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded comparatively higher values (2.75 and 2.68 cm) as compared all other treatments in both the years.

Table 4.13. Effect of crop establishment techniques and integrated nutrient management on yield attributing characters of sugarcane

Treatments	Millable cane length (cm)		Diameter of millable cane (cm)		Number of millable cane ('000/ha)		Average millable cane weight (kg)	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Crop establishment techniques (M)								
M ₁ : Conventional method	267.91	255.81	2.72	2.65	85.40	83.82	1.222	1.188
M ₂ : Bud chip seedling at 90 cm x 60 cm	272.11	261.70	2.72	2.66	88.44	87.28	1.256	1.222
M ₃ : Bud chip seedling at 120 cm x 60 cm	298.30	285.52	2.74	2.68	96.17	95.04	1.298	1.272
SEm±	4.45	5.25	0.05	0.04	1.86	1.70	0.013	0.014
CD (P=0.05)	17.46	20.59	NS	NS	7.30	6.68	0.050	0.055
Integrated nutrient management (F)								
F ₁ : 100% RDF	264.51	251.25	2.68	2.63	85.62	83.38	1.216	1.194
F ₂ : 100% RDF + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	286.39	275.53	2.75	2.68	92.04	91.04	1.280	1.246
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	283.94	273.26	2.75	2.67	91.66	90.77	1.270	1.232
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	281.50	269.58	2.74	2.67	90.87	89.58	1.267	1.222
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	279.72	268.75	2.73	2.67	90.57	88.88	1.254	1.212
SEm±	2.44	2.78	0.02	0.02	1.15	0.93	0.012	0.011
CD(0.05)	7.11	8.11	NS	NS	3.37	2.71	0.038	0.032
Interaction (M x F)								
SEm	4.22	4.81	0.03	0.03	2.01	1.61	0.022	0.021
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Note: DAP: Days after planting ; RDF: Recommended dose of fertilizer; GM: Green manuring; VC: Vermicompost; EC: Enriched compost; BF: Biofertilizers; SEm±: Standard error of mean; CD: Critical difference, NS: Non significant

Interaction effect

The interaction effect between crop establishment techniques and integrated nutrient management on diameter of millable cane was also found non-significant during both the years.

4.2.3 Number of millable cane ('000 ha⁻¹)

Number of millable of cane is considered as one of the most important yield attributing characters in sugarcane. Data regarding the number of millable cane are presented in Table 4.13 and corresponding analyses of variance are appended in Appendix XIII.

Effect of crop establishment techniques

The different crop establishment techniques significantly influenced the number of millable cane ('000 ha⁻¹) during both the years.

Data revealed that planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded significantly more number of millable canes (96.17 and 95.04 '000 ha⁻¹) as compared to planting of bud chip seedling at 90 cm x 60 cm (M₂) (88.44 and 87.28 '000 ha⁻¹) and conventional method of planting (M₁) (85.40 and 83.82 '000 ha⁻¹) during 2017-18 and 2018-19, respectively. However, M₁ and M₂ were at par in effect during both the years. The development of more number of shoots per unit area and their better survivability might have resulted in more number of millable canes under wider planting of bud chip seedling. On the other hand, the more competition for resources under narrow planting of both the crop establishment techniques *i.e.* M₁ and M₂ resulted in higher mortality of shoots which greatly reduced the number of millable cane. Soomro *et al.* (2009) also reported more number of millable canes under wider row spacing of 125 cm as compared to other narrow spacings. Similar results were also reported by Cheema *et al.* (2002), Chattha *et al.* (2007) and Chaudhari *et al.* (2014).

Effect of integrated nutrient management

The number of millable cane recorded at the time of harvesting were significantly varied due to different integrated nutrient management practices during both the years. Data presented in Table 4.13 clearly expressed that the number of millable canes produced per unit area greatly increased under the integrated nutrient management as compared to 100% RDF. It ranged from 85.62 to 92.04 '000 ha⁻¹ during 2017-18 and 83.38 to 91.04 '000 ha⁻¹ during 2018-19 under different treatments. In both

the years, significantly higher number of millable canes (92.04 and 91.04 '000 ha⁻¹) were obtained under the integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) which was at par with 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (91.66 and 90.77 '000 ha⁻¹), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (90.87 and 89.58 '000 ha⁻¹) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea¹ (F₅) (90.57 and 88.88 '000 ha⁻¹) during 2017-18 and 2018-19, respectively. Whereas, significantly lower values of 85.62 '000 ha⁻¹ in 1st year and 83.38 '000 ha⁻¹ in 2nd year were obtained in the treatment receiving 100% RDF (F₁). The significant reduction in number of millable canes under 100% RDF (F₁) might be due greater differences in sink and source that led to high mortality of tillers because of insufficient nutrient supply during the grand growth stages of sugarcane. While, the adequate supply of nutrients might have helped in augmentation of more shoot to millable cane conversion ratio under integrated nutrients management practices which resulted in more number of millable canes. Umesh *et al.* (2018) also reported maximum number of millable canes with the integration of organic manures with 100% RDF. Banerjee *et al.* (2018) reported significantly higher number of millable canes due to integrated supply of 75% RDN through inorganic source, biofertilizers along with 25% RDN through FYM as compared to 100% RDF. Kumar *et al.* (2019) also reported the similar findings.

Interaction effect

The crop establishment techniques and integrated nutrient management could not bring any significant effect on number of millable canes during both the years.

4.2.4 Average weight of millable cane (kg)

Data regarding average weight of millable cane are presented in Table 4.13 and corresponding analyses of variance are appended in Appendix XIII.

Effect of crop establishment techniques

The average weight of millable cane was significantly influenced by different crop established techniques during both the years.

Among the crop established techniques, planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded significantly higher weight of millable cane (1.298 and 1.272 kg) which was at par with planting of bud chip seedling at 90 cm x 60 cm (M₂)

(1.256 and 1.222 kg) but superior to conventional method of planting (M_1) (1.222 and 1.188 kg) during 2017-18 and 2018-19, respectively. However, M_1 and M_2 were also at par with each other during both the years. The planting of bud chip seedling at 120 cm row facilitated the crop for better exposure to all the resources that resulted in more cane length as well as cane diameter, thereby, increased the weight of millable cane. The significant reduction in average cane weight under conventional method might be due to decrease in values of parameters like cane length and cane diameter. The enhancement in individual cane weight under wider spacing in comparison to narrow spacing was also reported by Orgeron (2003), Raskar and Bhoi (2003) and Ghaffar *et al.* 2012. Chandrakar *et al.* (2019) also reported that planting of bud chip seedling at 120 cm \times 60 cm produced significantly higher single cane weight as compared to 3 budded setts planting.

Effect of integrated nutrient management

The integrated nutrient management practices significantly influenced the average weight of millable cane during both the years.

Data furnished in Table 4.13 in respect of average weight of millable cane revealed that integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F_2) recorded significantly higher values (1.280 kg, during 2017-18; 1.246 kg, during 2018-19) which were at par with 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F_3) (1.270 kg in 1st year and 1.232 kg in 2nd year), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F_4) (1.267 kg in 1st year and 1.222 kg in 2nd year) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F_5) (1.254 kg in 1st year and 1.212 kg 2nd year) during 2017-18, on the other hand, F_2 was at par with only F_3 and F_4 during 2018-19. Besides this, the average weight of millable cane recorded under 100% RDF (F_1) (1.216 kg) was at par with 75% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F_5) (1.254 kg) during 2017-18. Whereas, the average weight of millable cane recorded under F_1 (1.194 kg) was at par with both F_4 (1.222 kg) and F_5 (1.212 kg) in 2018-19.

The significant increase in average cane weight under integrated supply of organic sources, biofertilizers along with adequate dose of inorganic fertilizers might be due better supply of nutrients to the crop that resulted in more cane length as well as cane diameter and ultimately increased the weight of individual cane. Kumar *et al.*

(2017) also reported that the integrated application of FYM @ 15 t ha⁻¹ along with 100% RDF significantly enhanced the cane weight over 100% RDF.

Interaction effect

The interaction between the crop establishment techniques and integrated nutrient management failed to show any significant effect on weight of individual cane during both the years.

4.2.5 Length of internodes (cm)

The data regarding the length of internodes in bottom, middle and top portion of millable cane are presented in Table 4.14 and corresponding analyses of variance are appended in Appendix XIV.

4.2.5.1 Length of the internodes (Bottom)

Effect of crop establishment techniques

The length of the internodes recorded in bottom portion of a millable cane was significantly influenced by crop establishment techniques in both the years. The planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded significantly higher length of the internodes (10.61 and 10.42 cm) as compared to planting of bud chip seedling at 90 cm x 60 cm (M₂) (9.78 and 9.54 cm) and conventional method of planting (M₁) (9.70 and 9.43 cm) during 2017-18 and 2018-19, respectively. However, M₁ and M₂ were at par in effect during both the years. The availability of more nutrients and other resources under planting of bud chip seedling at 120 cm x 60 cm during the early stage of cane formation helped in more elongation of internodes in the bottom portion.

Effect of integrated nutrient management

The different integrated management nutrient practices significantly influenced the length of internodes of millable cane measured in bottom portion during both the years. All the integrated nutrient management treatments significantly increased the length of internodes of a millable cane as compared to 100% RDF (F₁), but all of them were at par with each other during both the years.

However, significantly higher values of 10.20 cm, during 2017-18 and 10.02 cm, during 2018-19 were obtained under the integrated application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) which was at par with 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring

Table 4.14. Effect of crop establishment techniques and integrated nutrient management on length of internodes and number of internodes cane⁻¹ of sugarcane

Treatments	Length of internodes (cm)						Number of internodes cane ⁻¹	
	Bottom		Middle		Top		2017-18	2018-19
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19		
Crop establishment technique (M)								
M ₁ : Conventional method	9.70	9.43	12.03	11.62	8.67	8.55	24.37	22.54
M ₂ : Bud chip seedling at 90 cm x 60 cm	9.78	9.54	12.82	12.53	8.88	8.78	25.50	23.84
M ₃ : Bud chip seedling at 120 cm x 60 cm	10.61	10.42	13.57	13.30	9.55	9.28	27.25	26.14
SEm±	0.18	0.19	0.29	0.28	0.17	0.16	0.33	0.34
CD (P=0.05)	0.72	0.76	1.12	1.10	0.68	0.63	1.28	1.32
Integrated nutrient management (N)								
F ₁ : 100% RDF	9.60	9.32	12.17	11.95	8.45	8.35	24.50	23.01
F ₂ : 100% RDF + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	10.20	10.02	13.15	12.83	9.51	9.14	26.27	25.04
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	10.16	9.95	12.94	12.60	9.18	9.12	26.25	24.36
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	10.12	9.88	12.90	12.55	9.12	8.88	25.88	24.20
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	10.07	9.82	12.86	12.48	9.08	8.84	25.63	24.16
SEm±	0.15	0.16	0.15	0.16	0.15	0.11	0.25	0.32
CD (P=0.05)	0.43	0.46	0.42	0.47	0.44	0.33	0.74	0.94
Interaction (M x F)								
SEm±	0.26	0.27	0.25	0.28	0.26	0.20	0.43	0.55
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Note: DAP: Days after planting ; RDF: Recommended dose of fertilizer; GM: Green manuring; VC: Vermicompost; EC: Enriched compost; BF: Biofertilizers; SEm±: Standard error of mean; CD: Critical difference, NS: Non significant

of cowpea (F₃) (10.16 cm during 2017-18 and 9.95 cm during 2018-19), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (10.12 cm during 2017-18 and 9.88 cm during 2018-19) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (10.07 cm during 2017-18 and 9.82 cm during 2018-19). The optimum availability of nutrients throughout the crop growing periods might have increased the length of the internodes.

Interaction effect

The interaction effect between crop establishment techniques and integrated nutrient management on length of the internodes recorded at bottom was found to be non-significant during both the years.

4.2.5.2 Length of the internodes (Middle)

Effect of crop establishment techniques

The crop establishment techniques significantly influenced the length of the internodes recorded in middle portion of a millable cane in both the years. Among the crop establishment techniques, planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded significantly higher length of the internodes (13.57 and 13.30 cm) which was at par with planting of bud chip seedling at 90 cm x 60 cm (M₂) (12.82 and 12.53 cm), but superior to conventional method of planting (M₁) (12.03 and 11.62 cm) during 2017-18 and 2018-19, respectively. However, M₁ and M₂ were at par in effect during both the years.

Effect of integrated nutrient management

The length of the internodes recorded in middle portion of a millable cane was significantly influenced due to different integrated nutrient management (INM) practices in both the years.

All the treatments receiving integrated supply of nutrients significantly increased the length of the internodes (middle) as compared to 100% RDF through inorganic fertilizers. But, all the integrated nutrient management treatments except 100% RDF were at par with each other during both the years. However, the application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded comparatively higher values (13.15 and 12.83 cm) followed by application of 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea

(F₃) (12.94 and 12.60 cm), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (12.90 and 12.55 cm) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (12.86 and 12.48 cm) during 2017-18 and 2018-19, respectively.

Interaction effect

The crop establishment techniques and integrated nutrient management practices did not reveal any significant interaction effect on length of the internodes recorded at middle portion of a millable cane during both the years.

4.2.5.3 Length of the internodes (Top)

Effect of crop establishment techniques

The different crop establishment techniques significantly influenced the length of the internodes recorded in top portion of a millable cane in both the years. Among the crop establishment techniques, planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded significantly higher length of the internodes (9.55 and 9.28 cm) than conventional method of planting (M₁) (8.67 and 8.55 cm) but were at par with planting of bud chip seedling at 90 cm x 60 cm (M₂) (8.88 and 8.78 cm) during 2017-18 and 2018-19, respectively. However, M₁ and M₂ did not differ in effect during both the years.

The above results clearly expressed that irrespective of crop establishment techniques, the length of internodes in the middle portion of the cane was comparatively more than the top and bottom portion. The reduction in crop growth during maturity resulted in decrease in length of internodes in top portion. While, the coincidence of growth stage with more availability of all the resources might be responsible for elongation of internodes in the middle portion. The length of internodes is a varietal character, however, crop management practices plays an important role in modifying the length of internodes. In the present investigation, the optimum availability of all resources due to wider spacing might have helped in increasing the length of internodes under planting of bud chip seedling at 120 cm x 60 cm. Khalid *et al.* (2015) also reported more length of internodes under the planting of bud chip seedling at 120 cm as compared to 90 cm spacing. The significant increase in internode length due to planting of bud chip seedling at 120 cm row spacing as compared to conventional method was also reported by Chandrakar *et al.* (2019).

Effect of integrated nutrient management

Significant variation in the length of the internodes in top portion was recorded due to different integrated nutrient management (INM) practices during both the years. The greater length of the internodes in top portion were recorded due to the application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) (9.51 and 9.14 cm) which was at par with 100% RDF + enriched compost @ 1t ha⁻¹ + green manuring of cowpea (F₃) (9.18 and 9.12 cm), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea+ biofertilizers @ 10 kg ha⁻¹ (F₄) (9.12 and 8.88 cm) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (9.08 and 8.84 cm) during 1st and 2nd year, respectively.

The significantly higher values obtained under the integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) might be due to more availability of nutrients supplied from suitable combination of different nutrient sources. Besides this, the release of growth hormones from vermicompost and biofertilizers like *Azotobacter* might have helped in elongation of crop internodes under this particular treatment. Shahid *et al.* (2011) also reported significant variation in the length of internodes due to various nutrient management practices in sugarcane. Kanjana and Pitchai (2009) also reported significant improvement in length of internodes with the combination of organic and inorganic plant nutrient sources along with biofertilizers. Similarly, Somroo *et al.* (2013) also reported significantly higher length of internodes due to integration of 75% RDF along with FYM @ 20 t ha⁻¹ or pressmud @ 20 t ha⁻¹ and both of them were found to be superior over 100% RDF.

Interaction effect

The interaction effect between crop establishment techniques and integrated nutrient management on length of the internodes recorded at top portion of a millable cane was found non-significant during both the years.

4.2.6 Number of internodes millable cane⁻¹

Data regarding the number of internodes are presented in Table 4.14 and corresponding analyses of variance are appended in Appendix XIV.

Effect of crop establishment techniques

The number of internodes millable cane⁻¹ recorded during harvesting was significantly influenced by different crop establishment techniques in both the years. The planting of bud chip seedling at 120 cm x 60 cm (M₃) registered significantly higher number of internodes millable cane⁻¹ (27.25 and 26.14) as compared to planting of bud chip seedling at 90 cm x 60 cm (M₂) (25.50 and 23.84) and conventional method (M₁) (24.37 and 22.54) during 2017-18 and 2018-19, respectively. But, both M₁ and M₂ were at par with each other during both the years. Significant variation in plant height under different crop establishment techniques resulted in significant difference in number of internodes millable cane⁻¹. Moreover, proper orientation of plants and better utilization of resources under wider planting of bud chip seedlings might have helped in more growth of cane stalk. Khalid *et al.* (2015) also reported more number of internodes plant⁻¹ due to planting of bud chip seedling at 120 cm spacing as compared to 90 cm row spacing.

Effect of integrated nutrient management

The different integrated nutrient management practices significantly influenced the number of internodes millable cane⁻¹ recorded during harvesting in both the years of investigation. Results clearly expressed that all the integrated nutrient management practices significantly increased the number of internodes millable cane⁻¹ as compared to 100% RDF in both the years. The maximum number of internodes were obtained due to application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + bio-fertilizers @ 10 kg ha⁻¹ (F₂) (26.27 and 25.04) which was at par with all the treatments comprising of both organic and inorganic fertilizers *viz.*, 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (26.25 and 24.36), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (25.88 and 24.20) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (25.63 and 24.16) during 1st and 2nd year, respectively. Whereas, the lowest number of internodes (24.50 during 2017-18 and 23.01 during 2018-19) were obtained under 100% RDF (F₁). The more cane length associated with the combined application of both organic and inorganic fertilizers resulted in more number of internodes millable cane⁻¹. Soomro *et al.* (2012) also reported significant increase in number of internodes plant⁻¹ (23.3) under the residual effect of FYM along with 75% RDF, whereas, the lowest value (15.0) was

observed under 100% RDF. Similarly, Keshavaiah (2012) also reported more number of internodes millable cane⁻¹ due to integrated application of nutrients over 100% RDF.

Interaction effect

The interaction between crop establishment techniques and integrated nutrient management did not show any significant effect on number of internodes of millable cane⁻¹ during both the years.

4.2.7 Cane yield (t ha⁻¹)

Data recorded on cane yield are presented in Table 4.15 and corresponding analyses of variance are appended in Appendix XV.

Effect of crop establishment techniques

The different crop establishment techniques clearly showed significant variation in cane yield for both the years as well as in pooled analysis. The planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded significantly higher cane yield of both individual year (123.20 t ha⁻¹ during 2017-18 and 118.64 t ha⁻¹ during 2018-19) as well as in pooled analysis (120.92 t ha⁻¹) as compared to the planting of bud chip seedling at 90 cm x 60 cm (M₂) (108.55, 105.38 and 106.98 t ha⁻¹ for 2017-18, 2018-19 and in pooled analysis, respectively) and conventional method (M₁) (102.92, 98.36 and 100.64 t ha⁻¹ for 2017-18, 2018-19 and in pooled analysis, respectively). The planting of bud chip seedling at 120 cm x 60 cm recorded 19.70, 17.89 and 20.15 % increased yield, respectively over conventional method for 2017-18, 2018-19 and in pooled analysis.

However, cane yield between M₁ and M₂ did not differ for both the years as well as in pooled yield. The excessive amount of rainfall received during the grand growth of sugarcane in case of 2nd year along with less BSSH (shown in Fig. 3.1.d) reduced the crop growth as well as yield as compared to 1st year crop.

The increase in entire yield attributing characters *viz.*, cane length, cane weight, number of millable cane under the planting of bud chip seedling at 120 cm x 60 cm (M₃) might be responsible for production of higher cane yield as compared to other crop establishment techniques. The significant increase in cane yield under the planting of bud chip seedling at 120 cm in comparison to 90 cm spacing was also reported by Rehman *et al.* (2013) and Khalid *et al.* 2015. Similarly, Mohanty *et al.* (2014) and Chandrakar *et al.* (2019) reported significantly higher cane yield under the planting of

Table 4.15. Effect of crop establishment techniques and integrated nutrient management on yield of sugarcane

Treatments	Cane yield (t ha ⁻¹)			Green top yield (t ha ⁻¹)			Trash yield (t ha ⁻¹)		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Crop establishment techniques (M)									
M ₁ : Conventional method	102.92	98.36	100.64	16.20	15.84	16.02	8.14	7.97	8.06
M ₂ : Bud chip seedling at 90 cm x 60 cm	108.55	105.38	106.98	17.08	16.48	16.78	8.65	8.33	8.49
M ₃ : Bud chip seedling at 120 cm x 60 cm	123.20	118.64	120.92	17.78	17.23	17.50	9.45	9.03	9.24
SEm±	2.95	2.05	2.44	0.22	0.24	0.23	0.13	0.14	0.17
CD (P=0.05)	11.58	8.03	9.56	0.86	0.94	0.88	0.52	0.55	0.70
Integrated nutrient management (F)									
F ₁ : 100% RDF	102.48	98.92	100.70	15.55	15.48	15.29	8.46	7.86	8.16
F ₂ : 100% RDF + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	115.46	111.11	113.28	17.68	16.94	17.33	8.94	8.74	8.84
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	113.94	109.87	111.91	17.53	16.84	17.14	8.85	8.61	8.73
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	113.40	108.77	111.09	17.28	16.78	16.87	8.82	8.51	8.67
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	112.72	108.21	110.46	17.06	16.49	16.68	8.68	8.48	8.58
SEm±	1.23	1.08	0.99	0.22	0.20	0.17	0.06	0.07	0.09
CD (P=0.05)	3.58	3.15	2.88	0.66	0.58	0.51	0.17	0.23	0.27
Interaction (M x F)									
SEm±	2.12	1.88	1.72	0.38	0.35	0.31	0.10	0.13	0.16
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: DAP: Days after planting ; RDF: Recommended dose of fertilizer; GM: Green manuring; VC: Vermicompost; EC: Enriched compost; BF: Biofertilizers; SEm±: Standard error of mean; CD: Critical difference, NS: Non significant

bud chip seedling at 120 cm x 60 cm as compared to conventional method. Several researchers also reported 120 cm as optimum row to row spacing for getting higher cane yield in sugarcane (Ahmad, 2002; Mahadevaswamy and Martin, 2002 and Munsif *et al.*, 2015).

Effect of integrated nutrient management

The cane yield of sugarcane was significantly influenced by different integrated nutrient management practices during both the years. All the treatments comprised of integrated nutrient management recorded significantly higher cane yield as compared to 100% RDF for both the years as well as in pooled analysis. Among the treatments, the integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher cane yield (115.46, 111.11 and 113.28 t ha⁻¹ for 2017-18, 2018-19 and in pooled analysis, respectively) which was at par with 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (113.94, 109.87 and 111.91 t ha⁻¹ for 2017-18, 2018-19 and in pooled analysis, respectively), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + bio-fertilizers @ 10 kg ha⁻¹ (F₄) (113.40 108.77 and 111.09 t ha⁻¹ for 2017-18, 2018-19 and in pooled analysis, respectively) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (112.72, 108.21 and 110.46 t ha⁻¹ for 2017-18, 2018-19 and in pooled analysis, respectively). All the above treatments were significantly higher over 100% RDF (F₁) (102.48, 98.92 and 100.70 t ha⁻¹ for 2017-18, 2018-19 and in pooled analysis, respectively). In earlier research, More *et al.* (2009) also reported insignificant difference in cane yield due to incorporation of green manure crop with 100% RDF as well as 75% RDF. The per cent increase in cane yield under the treatments F₂, F₃, F₄ and F₅ over 100% RDF (F₁) was 12.67, 11.18, 10.66 and 9.99%, respectively, during 2017-18; 12.32, 11.07, 9.96 and 9.30%, respectively, during 2018-19; 12.49, 11.13, 10.32 and 9.69%, respectively, in pooled analysis.

The better crop growth as well as yield attributing parameters *viz.*, under the treatment F₂ led to higher cane yield. Umesh *et al.* (2013) reported that the integration of organic nutrient sources with higher rates of fertilizers produced comparatively more cane yield than integration with lower rates. The beneficial effect of FYM and biofertilizers in combination with inorganic fertilizers was also reported by Yadav *et al.* (2018). Significantly superior cane yield over 100% RDF due to integrated

application FYM @ 10 t ha⁻¹ and biofertilizers along with 100% NPK was also reported by Kumar *et al.* (2017). Many researchers reported that integrated supply of both organic as well as inorganic sources of nutrient produced significantly higher yield over 100% RDF (Gangwar and Sharma, 1998; Kumar and Chand, 2013; Kumar *et al.* (2016) and Banerjee *et al.*, 2018).

Interaction effect

The interaction between the crop establishment techniques and integrated nutrient management failed to exert any significant effect on cane yield during both the years.

4.2.8 Green top yield (t ha⁻¹)

The data in respect of green top yield are presented in Table 4.15 and corresponding analyses of variance are appended in Appendix XV.

Effect of crop establishment techniques

The green top yield recorded during harvesting was significantly influenced by different crop establishment techniques for both the years of investigation as well as in pooled analysis. The planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded significantly higher green top yield (17.78, 17.23 and 17.50 t ha⁻¹ for 1st year, 2nd year and in pooled analysis) that was at par with planting of bud chip seedling at 90 cm x 60 cm (M₂) (17.08, 16.48 and 16.78 t ha⁻¹ for 1st year, 2nd year and in pooled analysis), but superior to the yield recorded under conventional method (M₁) (16.20, 15.84 and 16.02 t ha⁻¹ for 1st year, 2nd year and in pooled analysis). In case of both individual year as well as well as in pooled data, the green top yield recorded under M₁ and M₂ was at par with each other.

The significant variation in number of millable canes per unit area amongst the treatments resulted in significant difference in green top yield. The more number of millable canes produced under wider planting of bud chip seedling increased the green top yield of sugarcane. Ehsanullah *et al.* (2011) also reported significant variation in green top yield due to planting of sugarcane setts under different row spacing. They reported significantly higher green top weight (12.69 t ha⁻¹) due to planting of sugarcane at 120 cm spaced 3-row strips which was at par with 90 cm spaced 2-row strips (11.18 t ha⁻¹).

Effect of integrated nutrient management

The different integrated nutrient management practices showed significant variation in green top yield during both the years of investigation. Result revealed that all the treatments comprised of both organic and inorganic sources of nutrients recorded significantly higher green top yield in comparison to 100% RDF (F₁) in both the years. The application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded the maximum values of 17.68 t ha⁻¹ in 2017-18 and 16.94 t ha⁻¹ in 2018-19 which was at par with 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (17.53 and 16.84 t ha⁻¹), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + bio-fertilizers @ 10 kg ha⁻¹ (F₄) (17.28 and 16.78 t ha⁻¹) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (17.06 and 16.49 t ha⁻¹) in 1st and 2nd year, respectively. Whereas, significantly lower yield of 15.55 t ha⁻¹ in 2017-18 and 15.48 t ha⁻¹ in 2018-19 was obtained under the treatment receiving 100% RDF through inorganic fertilizers (F₁).

The pooled data furnished in Table 4.15 also revealed that all the integrated nutrient management practices recorded significantly higher green top yield as compared to 100% RDF (F₁). However, significantly higher value (17.33 t ha⁻¹) was obtained under the treatment receiving 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) that was at par with the application of 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (17.14 t ha⁻¹), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + bio-fertilizers @ 10 kg ha⁻¹ (F₄) (16.87 t ha⁻¹), but superior to the treatment receiving 75% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (16.68 t ha⁻¹). But, the effect of F₃, F₄ and F₅ did not differ from each other. All the above treatments recorded significantly higher green top yield in pooled analysis than the 100% RDF (15.29 t ha⁻¹). The production of more number of millable canes under integrated application of both organic and inorganic sources of nutrients might be responsible for increase in green top yield. Shahid *et al.* (2011) also reported significant variation in green top yield due to different nutrient management practices. They reported significantly higher green top yield (14.64 t ha⁻¹) due to integration of biocane 1.25 l ha⁻¹ + N: P: K @ 170:85:85 kg ha⁻¹ as compared to sole inorganic fertilizers (12.44 t ha⁻¹) as well as other treatment combinations in autumn planted sugarcane.

Interaction effect

The interaction effect between crop establishment techniques and integrated nutrient management on green top yield was found non-significant during both the years.

4.2.9 Trash yield ((t ha⁻¹))

The data regarding trash yield are presented in Table 4.15 and corresponding analyses of variance are appended in Appendix XV.

Effect of crop establishment techniques

The trash yield recorded during harvesting was significantly influenced by different crop establishment techniques for both the years as well as in pooled analysis. Planting of bud chip seedling at 120 cm x 60 cm (M₃) produced significantly higher trash yield (9.45, 9.03 and 9.24 t ha⁻¹ for 1st year, 2nd year and in pooled analysis, respectively) as compared to planting of bud chip seedling at 90 cm x 60 cm (M₂) (8.65, 8.33 and 8.49 t ha⁻¹ for 1st year, 2nd year and in pooled analysis, respectively) and convention method (M₁) (8.14, 7.97 and 8.06 t ha⁻¹ for 1st year, 2nd year and in pooled analysis, respectively). However, the effect of both M₁ and M₂ were at par for both individual years as well as in pooled analysis.

Effect of integrated nutrient management

Results revealed significant differences in trash yield under different integrated nutrient managements for both the years as well as in pooled analysis. All the integrated nutrient management practices recorded significantly higher trash yield in comparison to 100% RDF (F₁) in both the years as well as in pooled analysis. The integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) produced significantly higher trash yield (8.94, 8.74 and 8.84 t ha⁻¹ for 2017-18, 2018-19 and in pooled analysis) which was at par with the application of 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (8.85, 8.61 and 8.73 t ha⁻¹ for 2017-18, 2018-19 and in pooled analysis) and 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + bio-fertilizers @ 10 kg ha⁻¹ (F₄) (8.82, 8.51 and 8.67 t ha⁻¹ for 2017-18, 2018-19 and in pooled analysis), but superior to the application of 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (8.68, 8.48 and 8.58 t ha⁻¹ for 2017-18, 2018-19 and in pooled analysis). However, F₃, F₄ and F₅ were at

par with each other during both the years of investigation. The lowest trash yield was obtained under F_1 (8.46, 7.86 and 8.16 t ha⁻¹ for 2017-18, 2018-19 and in pooled analysis).

The production of more number of millable canes under integrated application of both organic and inorganic sources of nutrients might be responsible for increase in trash yield. Shahid *et al.* (2011) also reported significant variation in trash yield due to different nutrient management practices. They reported significantly higher trash yield (8.42 t ha⁻¹) due to integration of biocane 1.25 l ha⁻¹ along with N: P: K @ 170:85:85 kg ha⁻¹ as compared to sole inorganic fertilizers (7.67 t ha⁻¹) as well as other treatment combinations in autumn planted sugarcane.

Interaction effect

The interaction between crop establishment techniques and integrated nutrient management failed to exert any significant effect on trash yield during both the years as well as pooled analysis.

4.2.9 Biological yield (t ha⁻¹)

The data pertaining to biological yield are presented in Table 4.16 and corresponding analyses of variance are appended in Appendix XV.

Effect of crop establishment techniques

The different crop establishment techniques revealed significant variation in biological yield during both the years. The planting of bud chip seedling at 120 cm x 60 cm (M_3) recorded significantly higher biological yield (150.38 and 144.54 t ha⁻¹) as compared to the planting of bud chip seedling at 90 cm x 60 cm (M_2) (134.28 and 130.18 t ha⁻¹) as well as conventional method (M_1) (127.26 and 122.11 t ha⁻¹) during 2017-18 and 2018-19, respectively. However, M_1 and M_2 did not differ from each other during both the years. The production of higher top, trash and cane yield under planting of bud chip seedling at 120 cm x 60 cm (M_3) ultimately resulted in higher biological yield.

Effect of integrated nutrient management

Data provided in Table 4.16 indicated significant variation in biological yield under different integrated nutrient management practices during both the years. All the treatments comprised of integrated supply of different sources of nutrients recorded significantly higher biological yield as compared to 100% RDF (F_1). However,

comparatively higher biological yield (142.08 and 136.78 t ha⁻¹) was obtained due to the application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) followed by the treatments receiving 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (140.32 and 135.16 t ha⁻¹), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + bio-fertilizers @ 10 kg ha⁻¹ (F₄) (139.50 and 133.53 t ha⁻¹) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (138.46 and 133.02 t ha⁻¹) during 2017-18 and 2018-19, respectively. But, no significant variation existed among F₂, F₃, F₄ and F₅ during both the years. While, the lowest biological yield of 126.49 t ha⁻¹ during 2017-18 and 120.02 t ha⁻¹ during 2018-19 were registered under 100% RDF (F₁).

The significant variation in green top, trash as well as cane yield resulted in deviation in biological yield among the treatments. The higher production of green top, trash as well as cane yield under the treatments receiving both organic as well as inorganic sources of nutrients resulted in higher biological yield as compared to 100% RDF.

Interaction effect

The biological yield was found non- significant due to the interaction effect between the crop establishment techniques and integrated nutrient management during both the years.

4.2.10 Harvest index (%)

The data pertaining to harvest index as affected by crop establishment techniques and integrated nutrient management are presented in Table 4.16 and corresponding analyses of variance are presented in Appendix XV.

Effect of crop establishment techniques

The different crop establishment techniques showed insignificant difference in harvest index during both the years. Though non-significant, planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded comparatively higher index of 81.92% during 2017-18 and 82.10% during 2018-19 as compared to other crop establishment techniques. Maqsood *et al.* (2005) also reported insignificant difference in harvest index due to planting of sugarcane under different row spacing.

Table 4.16. Effect of crop establishment techniques and integrated nutrient management on biological yield and harvest index of sugarcane

Treatments	Biological yield (t ha ⁻¹)		Harvest index (%)	
	2017-18	2018-19	2017-18	2018-19
Crop establishment techniques (M)				
M ₁ :Conventional method	127.26	122.11	80.87	80.70
M ₂ : Bud chip seedling at 90 cm x 60 cm	134.28	130.18	80.84	80.93
M ₃ :Bud chip seedling at 120 cm x 60 cm	150.38	144.54	81.92	82.10
SEm±	2.16	3.21	1.18	1.21
CD (P=0.05)	8.50	12.71	NS	NS
Integrated nutrient management (F)				
F ₁ : 100% RDF	126.49	122.02	81.02	81.06
F ₂ : 100% RDF + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	142.08	136.78	81.26	81.23
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	140.32	135.16	81.20	81.28
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	139.50	133.53	81.29	81.45
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	138.46	133.02	81.41	81.36
SEm±	1.40	1.46	0.72	0.58
CD (P=0.05)	4.08	4.28	NS	NS
Interaction (M x F)				
SEm±	2.42	2.54	1.24	1.00
CD (P=0.05)	NS	NS	NS	NS

Note: DAP: Days after planting ; RDF: Recommended dose of fertilizer; GM: Green manuring; VC: Vermicompost; EC: Enriched compost; BF: Biofertilizers; SEM±: Standard error of mean; CD: Critical difference, NS: Non significant

Effect of integrated nutrient management

The different integrated nutrient management practices failed to show any significant differences in harvest index in both the years of investigation.

Interaction effect

The interaction effect between the crop establishment techniques and integrated nutrient management on harvest index was found non-significant during both the years.

4.3 Qualitative studies

The data in respect of qualitative studies *viz.*, field brix, juice recovery, sucrose, purity, and commercial cane sugar (%) as well as commercial cane sugar (CCS) (t ha^{-1}) as affected by crop establishment techniques and integrated nutrient management are presented in Table 4.17a and 4.17b and corresponding analyses of variance are appended in Appendix XVI and XVII.

4.3.1 Field brix (%)

The quantification of juice quality parameters like field brix (%) is very important for determination of proper harvesting time. The data on juice quality parameters such as field brix (%) as influenced by crop establishment techniques and integrated nutrient management are presented in Table 4.17a and corresponding analyses of variance are appended in Appendix XVI.

4.3.1.1 Field brix at bottom (%)

Effect of crop establishment techniques

The field brix content recorded at bottom portion of standing millable cane at 360 and 420 DAP were not significantly affected due to different crop establishment techniques in both the years. However, in both stages of the crop, an increasing trend was observed due to planting of bud chip seedling at 120 cm x 60 cm (M_3) (19.67 and 22.64%, respectively, during 2017-18; 19.03 and 22.54%, respectively, during 2018-19) followed by planting of bud chip seedling at 90 cm x 60 cm (M_2) (19.60 and 22.47%, respectively, during 2017-18; 19.02 and 22.50%, respectively, during 2018-19) and conventional method (M_1) (19.43 and 22.23%, respectively, during 2017-18; 18.56 and 22.38%, respectively, during 2018-19).

Effect of integrated nutrient management

The application of various integrated nutrient management practices did not exhibit any significant difference on field brix content at bottom portion of standing millable cane recorded at 360 and 420 DAP during both the years. But, the treatments receiving integrated nutrient management practices recorded comparatively higher values as compared 100% RDF in both the years. At 360 and 420 DAP, the application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded comparatively higher field brix content (19.86 and 22.55%, respectively, during 2017-18; 19.07 and 22.71%, respectively, during 2018-19).

Interaction effect

The field brix content recorded at bottom portion of standing millable cane remained unaffected due to interaction between the crop establishment techniques and integrated nutrient management during both the years.

4.3.1.2 Field brix at middle (%)

Effect of crop establishment techniques

The different crop establishment techniques did not exert any significant effect on field brix content recorded at middle portion of standing millable cane at 360 and 420 DAP. In both the stages, planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded comparatively higher values (18.11 and 21.57%, respectively, during 2017-18; 17.40 and 21.48%, respectively, during 2018-19) as compared to planting of bud chip seedling at 90 cm x 60 cm (M₂) (17.96 and 21.42%, respectively, during 2017-18; 17.10 and 21.38%, respectively, during 2018-19) and conventional method (M₁) (17.44 and 21.22%, respectively, during 2017-18; 16.84 and 21.33%, respectively, during 2018-19).

Effect of integrated nutrient management

The various integrated nutrient management practices did not show any significant variation on field brix content of middle portion of standing millable cane recorded at 360 and 420 DAP during both the years. Though non-significant, the application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded comparatively higher values (18.11 and 21.64%, respectively, during 2017-18; 17.18 and 21.54%, respectively, during 2018-19) as compared to all other treatments in both the stages. Whereas, the minimum values

(17.60 and 21.04%, respectively, during 2017-18; 16.78 and 21.24%, respectively, during 2018-19) were obtained under 100% RDF (F₁).

Interaction effect

The crop establishment techniques and integrated nutrient management did not exert any significant effect on field brix content recorded at middle portion of standing millable cane during both the years.

4.3.1.3 Field brix at top (%)

Effect of crop establishment techniques

The field brix content recorded at top portion of a standing millable cane at 360 and 420 DAP did not differ due to different crop establishment techniques in both the years. But, comparatively higher values (14.08 and 20.49%, respectively, during 2017-18; 13.40 and 20.51%, respectively, during 2018-19) were achieved due to planting of bud chip seedling at 120 cm x 60 cm (M₃) as compared to planting of bud chip seedling at 90 cm x 60 cm (M₂) (14.04 and 20.41%, respectively, during 2017-18; 13.32 and 20.41%, respectively, during 2018-19) and conventional method (M₁) (13.71 and 19.88%, respectively, during 2017-18; 13.16 and 20.08%, respectively, during 2018-19) in both the stages of crop growth.

In a nut shell, the field brix content recorded at 420 DAP was comparatively more as compared to 360 DAP irrespective of crop establishment techniques during both the years. Except bottom portion of the cane, the field brix content in middle as well as top portion was found to be less than even 20% at 360 DAP, which gradually increased with the duration of the crop and reached the maximum values at 420 DAP. The difference in field brix content in bottom, middle and top portion of cane was much higher during 360 DAP, while the differences were very minimal at 420 DAP. Ahmed *et al.* (2011) also reported that row spacing did not influence the brix% in sugarcane juice of plant cane at the time of harvesting.

Effect of integrated nutrient management

Various integrated nutrient management practices did not influence the field brix content of top portion recorded at 360 and 420 DAP during both the years. In both the stages, the application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded comparatively higher values (14.07 and 20.44%, respectively, during 2017-18; 13.42 and 20.54%,

respectively, during 2018-19) as compared to all other treatments. Whereas, the minimum values (13.75 and 20.07%, respectively, during 2017-18; 13.11 and 20.13%, respectively, during 2018-19) were obtained under 100% RDF (F₁).

The above results clearly indicated that, although non-significant, the integrated supply of different organic sources of nutrients along with both 100 and 75% RDF slightly increased the field brix content over the sole application of 100% RDF. Irrespective of treatments, the field brix content recorded at 420 DAP was comparatively higher than 360 DAP. The field brix content recorded at 360 DAP showed large variation at bottom, middle and top portion of the cane which narrowed down during 420 DAP indicating the maturity of the crop at this particular stage. Although, all the treatments were found to be at par with each other, an increasing trend in field brix content was observed with the combination of organic sources of nutrients, biofertilizers along with 100% RDF in comparison to 100% RDF alone. Several researchers reported insignificant difference in brix content due to application different integrated nutrient management practices (Umesh *et al.*, 2013; Kumar and Gaddanakeri, 2015).

Interaction effect

The interaction effect between crop establishment techniques and integrated nutrient management in field brix content of top portion of standing millable cane was found non-significant in both the years.

4.3.2 Juice recovery or extraction (%)

The data pertaining to juice recovery or extraction (%) as influenced by crop establishment techniques and integrated nutrient management are presented in Table 4.17b and corresponding analyses of variance are appended in Appendix XVI.

Effect of crop establishment techniques

The juice recovery or extraction percentage remained unaffected due to different crop establishment techniques during both the years. The juice extraction percentage ranged from 58.78 to 61.56% during 2017-18 and 57.94 to 60.75% during 2018-19 under different crop establishment techniques. But, slightly higher values were obtained under the planting of bud chip seedling at 120 cm x 60 cm (M₃) (61.56 and 60.75%) and 90 cm x 60 cm (M₂) (60.84 and 59.20%) in comparison to conventional method (M₁) (58.78 and 57.94%) in 1st and 2nd year, respectively.

Table 4.17 a. Effect of crop establishment techniques and integrated nutrient management on qualitative studies (field brix) of sugarcane

Treatments	Field brix (%)											
	2017-18						2018-19					
	360 DAP			420 DAP			360 DAP			420 DAP		
	Bottom	Middle	Top	Bottom	Middle	Top	Bottom	Middle	Top	Bottom	Middle	Top
Crop establishment techniques (M)												
M ₁ : Conventional method	19.43	17.44	13.71	22.23	21.22	19.88	18.56	16.84	13.16	22.38	21.33	20.08
M ₂ : Bud chip seedling at 90 cm x 60 cm	19.60	17.96	14.04	22.47	21.42	20.41	19.02	17.10	13.32	22.50	21.38	20.41
M ₃ : Bud chip seedling at 120 cm x 60 cm	19.67	18.11	14.08	22.64	21.57	20.49	19.03	17.40	13.40	22.54	21.48	20.51
SEm±	0.51	0.36	0.33	0.32	0.30	0.50	0.36	0.34	0.23	0.63	0.40	0.44
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Integrated nutrient management (F)												
F ₁ : 100% RDF	19.21	17.60	13.75	22.27	21.04	20.07	18.78	16.78	13.11	22.18	21.24	20.13
F ₂ : 100% RDF + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	19.86	18.11	14.07	22.55	21.64	20.44	19.07	17.18	13.42	22.71	21.54	20.54
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	19.66	17.98	14.05	22.53	21.56	20.35	19.01	17.13	13.33	22.58	21.48	20.48
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	19.60	17.78	13.92	22.51	21.41	20.30	18.88	17.03	13.20	22.53	21.43	20.39
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	19.47	17.73	13.8	22.43	21.37	20.15	18.84	16.94	13.21	22.36	21.28	20.35
SEm±	0.22	0.29	0.20	0.21	0.19	0.20	0.24	0.16	0.17	0.23	0.14	0.15
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (M x F)												
SEm±	0.39	0.50	0.34	0.37	0.34	0.35	0.41	0.26	0.29	0.39	0.24	0.33
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: DAP: Days after planting; RDF: Recommended dose of fertilizer; GM: Green manuring; VC: Vermicompost; EC: Enriched compost; BF: Biofertilizers; SEm±: Standard error of mean; CD: Critical difference, NS: Non significant

Table 4.17 b. Effect of crop establishment techniques and integrated nutrient management on qualitative studies (Juice recovery, juice quality parameters and CCS yield) of sugarcane

Treatments	Juice recovery (%)		Sucrose (%)		Purity (%)		CCS (%)		CCS (t ha ⁻¹)	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Crop establishment technique (M)										
M ₁ : Conventional method	58.78	57.94	17.38	17.04	82.94	82.14	11.46	10.96	11.78	10.78
M ₂ : Bud chip seedling at 90cmx 60 cm	60.84	59.20	17.47	17.36	83.71	82.38	11.73	11.22	12.73	11.82
M ₃ : Bud chip seedling at 120cmx 60 cm	61.56	60.75	17.75	17.50	84.58	83.18	11.87	11.76	14.62	13.95
SEm±	0.82	0.95	0.31	0.25	0.98	1.13	0.15	0.16	0.28	0.34
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	1.12	1.34
Integrated management Practices (F)										
F ₁ : 100% RDF	56.46	55.23	17.26	17.11	83.11	81.52	11.38	11.13	11.60	11.04
F ₂ : 100% RDF + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	61.92	60.78	17.67	17.51	84.62	83.44	11.94	11.77	13.78	13.08
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	61.67	60.72	17.62	17.45	84.43	83.22	11.84	11.72	13.50	12.77
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	61.12	60.24	17.59	17.25	83.40	82.43	11.78	11.36	13.35	12.35
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	60.58	59.52	17.55	17.18	83.28	82.12	11.66	11.30	13.20	12.22
SEm±	0.47	0.51	0.13	0.12	0.75	0.73	0.14	0.18	0.13	0.17
CD (P=0.05)	1.38	1.50	NS	NS	NS	NS	0.42	0.52	0.38	0.48
Interaction (M x F)										
Sem±	0.82	0.89	0.22	0.21	1.30	1.26	0.26	0.31	0.23	0.29
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: DAP: Days after planting; RDF: Recommended dose of fertilizer; GM: Green manuring; VC: Vermicompost; EC: Enriched compost; BF: Biofertilizers; SEM±: Standard error of mean; CD: Critical difference, NS: Non significant

Effect of integrated nutrient management

The different integrated nutrient management practices significantly influenced the juice recovery (%) during both the years. All the integrated nutrient management practices significantly increased the juice recovery percentage as compared to 100% RDF, but at par with each other during both the years. However, comparatively higher percentage of juice recovery (61.92 and 60.78%) was obtained due to the application of 100% RDF + vermicompost @ 1t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) immediately followed by the treatment receiving 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (61.67 and 60.72%), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + bio-fertilizers @ 10 kg ha⁻¹ (F₄) (61.12 and 60.24%) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (60.58 and 59.52%) during 2017-18 and 2018-19, respectively. Whereas, significantly lower values were obtained under 100% RDF (F₁) (56.46 and 55.23%) in the respective years. The optimal supply of nutrients throughout crop growing period under the integrated nutrient management might have increased the succulency that resulted in higher juice recovery.

Interaction effect

The crop establishment techniques and integrated nutrient management practices did not show any significant interaction effect in juice extraction (%) during both the years.

4.3.3 Sucrose (%)

Effect of crop establishment techniques

The sucrose content in juice at the time of harvesting remained unaffected due to different crop establishment techniques in both the years. However, planting of bud chip seedling at 120 cm x 60 cm (M₃) and 90 cm x 60 cm (M₂) slightly increased the sucrose content in juice (17.75 and 17.47%, respectively in 2017-18; 17.50 and 17.36%, respectively in 2018-19) as compared to the conventional method of planting (M₁) (17.38 and 17.04%, in 2017-18 and 2018-19, respectively).

Effect of integrated nutrient management

The different integrated nutrient management did not exhibit any significant difference on sucrose content in juice during both the years of investigation.

However, the integrated nutrient management practices recorded comparatively higher values as compared to 100% RDF through inorganic fertilizers during both the years. Though non-significant, the combined application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded higher sucrose content of 17.67% in 1st year and 17.51% in 2nd year as compared to all other treatments.

Interaction effect

The interaction effect between crop establishment techniques and integrated nutrient management did not show any significant difference on sucrose content of juice during both the years.

4.3.4 Purity (%)

Effect of crop establishment techniques

The different crop establishment techniques did not show any significant difference in purity (%) of juice during both the years of investigation. However, planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded comparatively higher sucrose content (84.58 and 83.18%) as compared to planting of bud chip seedling at 90 cm x 60 cm (M₂) (83.71 and 82.38%) as well as conventional method of planting (M₁) (82.94 and 82.14%) in 1st and 2nd year, respectively. Chandrakar *et al.* (2019) also reported insignificant difference in purity (%) of juice due to planting of sugarcane bud chip seedling under different planting geometry. This is in conformity of earlier finding reported by Shukla and Lal (2003).

Effect of integrated nutrient management

The purity (%) of juice remained unaffected due to integrated nutrient management practices during both the years of investigation. But, the integrated nutrient management practices recorded comparatively higher values as compared to application of inorganic fertilizers alone in both the years. Among the treatments, the combined application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded comparatively higher values (84.62% in 1st year and 83.44% in 2nd year) as compared to all other treatments. Sinha *et al.* (2014) also reported that integrated nutrient management practices did not influence the purity per cent of juice of sugarcane.

Interaction effect

The purity (%) of juice was not significantly influenced due to interaction between crop establishment techniques and integrated nutrient management during both the years.

4.3.5 Commercial cane sugar (CCS) (%)

Effect of crop establishment techniques

The commercial cane sugar (CCS) (%) in juice at the time of harvesting was not significantly influenced by different crop establishment techniques during both the years. However comparatively higher content of CCS (11.87% in 1st year and 11.76% in 2nd year) were obtained due to planting of bud chip seedling at 120 cm x 60 cm (M₃) as compared to other crop establishment techniques.

Effect of integrated nutrient management

Significant variation in commercial cane sugar (CCS) content in juice was obtained due to different integrated nutrient management practices during both the years. The integrated application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher content of CCS (11.94% during 2017-18 and 11.77% during 2018-19) as compared to 100% RDF alone (F₁) (11.38 and 11.13%) but was at par with the application of 100% RDF + green manuring of cowpea + enriched compost @ 1 t ha⁻¹ (F₃) (11.84 and 11.72%), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + bio-fertilizers @ 10 kg ha⁻¹ (F₄) (11.78 and 11.36%) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (11.66 and 11.30%) during 1st and 2nd year, respectively. But, the integration of different sources of nutrients along with 75% RDF *i.e.* F₄ and F₅ were found at par with the treatment receiving 100% RDF (F₁) during both the years. Kumar and Chand (2013) also reported significant increase in CCS% due to *in situ* incorporation of green manuring crop or FYM along with RDF in comparison to RDF alone. Umesh *et al.* (2013) and Thakur *et al.* (2012) also reported significant improvement in CCS% as compared to 100% RDF.

Interaction effect

The interaction effect between crop establishment techniques and integrated nutrient management could not bring any significant variation on CCS % in juice during both the years.

4.3.6 Commercial cane sugar (CCS) yield (t ha^{-1})

Effect of crop establishment techniques

The commercial cane sugar (CCS) yield was significantly influenced by different crop establishment techniques that ranged from 11.78 to 14.62 t ha^{-1} during 2017-18 and 10.78 to 13.95 t ha^{-1} during 2018-19. The planting of bud chip seedling at 120 cm x 60 cm (M_3) significantly increased the CCS yield (14.62 and 13.95 t ha^{-1}) over the plating of bud chip seedling at 90 cm x 60 cm (M_2) (12.73 and 11.82 t ha^{-1}) and conventional method of planting (M_1) (11.78 and 10.78 t ha^{-1}) during 2017-18 and 2018-19, respectively. However, effect of M_1 and M_2 was at par with each other during both the years. The higher cane production as well as juice recovery (%) under the planting of bud chip seedling at 120 cm x 60 cm (M_3) might be responsible for production of higher sugar yield.

Effect of integrated nutrient management

Significant variation on commercial cane sugar (CCS) yield was observed due to different integrated nutrient management practices during both the years. Among the treatments, the integrated application of 100% RDF + vermicompost @ 1 t ha^{-1} + green manuring of cowpea + biofertilizers @ 10 kg ha^{-1} (F_2) recorded significantly higher CCS yield (13.78 and 13.08 t ha^{-1}) which was at par with 100% RDF + enriched compost @ 1 t ha^{-1} + green manuring of cowpea (F_3) (13.50 and 12.77 t ha^{-1}), but superior to 75% RDF + FYM @ 5 t ha^{-1} + vermicompost @ 1 t ha^{-1} + green manuring of cowpea + bio-fertilizers @ 10 kg ha^{-1} (F_4) (13.35 and 12.35 t ha^{-1}) and 75% RDF + FYM @ 5 t ha^{-1} + enriched compost @ 1 t ha^{-1} + green manuring of cowpea (F_5) (13.20 and 12.22 t ha^{-1}) in 1st and 2nd year, respectively. In both the years, significantly lower CCS yield was obtained under 100% RDF (F_1) (11.60 and 11.04 t ha^{-1}). The higher cane yield as well as increased percentage of CCS under the integrated supply of 100% RDF + vermicompost @ 1 t ha^{-1} + green manuring of cowpea + biofertilizers @ 10 kg ha^{-1} (F_2) resulted in higher sugar yield during both the years. Umesh *et al.* (2013) also reported that the addition of organic nutrients in combination with 100% RDF significantly improved the commercial cane sugar yield than the inorganic fertilizers alone. Meena *et al.* (2018) also reported significant improvement in CCS yield (10.8 t ha^{-1}) due to application of FYM @ 10 t ha^{-1} along with biofertilizers (*Azotobacter* + PSB) @ 12.5 kg ha^{-1} each) and inorganic fertilizers as compared to 100% RDF alone. This is in conformity of earlier findings of Virdia and Patel (2010).

Interaction effect

The interaction effect between crop establishment techniques and integrated nutrient management on commercial cane sugar (CCS) yield was found to be non-significant during both the years.

4.4 Jaggery recovery (%) and jaggery yield (t ha⁻¹)

The data regarding jaggery recovery (%) and jaggery yield (t ha⁻¹) are presented in Table 4.18 and corresponding analyses of variance are appended in Appendix XVIII

4.4.1 Jaggery recovery (%)

Effect of crop establishment techniques

The different crop establishment techniques did not influence the recovery percentage of jaggery during both the years. Though non-significant, comparatively higher percentage of jaggery (9.12 and 9.05 %) was recorded under the planting of bud chip seedling at 120 cm x 60 cm (M₃) followed by planting of bud chip seedling at 90 cm x 60 cm (M₂) (9.08 and 8.81%) and conventional method of planting (M₁) (8.77 and 8.74%) in 1st and 2nd year, respectively.

Effect of integrated nutrient management

The integrated nutrient management significantly influenced the recovery percentage of jaggery in both the years. The integrated application of both organic and inorganic sources of nutrients significantly increased the jaggery recovery (%) over 100% RDF during both the years. Among the treatments, the application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher jaggery recovery (9.24 and 9.12%) that was at par with 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (9.22 and 9.10%), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + bio-fertilizers @ 10 kg ha⁻¹ (F₄) (8.98 and 8.90%) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (8.96 and 8.85%) during 2017-18 and 2018-19, respectively. Whereas, significantly lower jaggery recovery of 8.56% in 1st year and 8.36% in 2nd year were obtained under 100% RDF (F₁). The optimum supply of nutrients under integrated nutrient management helped in more recovery of jaggery as compared to inorganic fertilizer alone.

Table 4.18. Effect of crop establishment techniques and integrated nutrient management on Jaggery recovery and jaggery yield of sugarcane

Treatments	Jaggery recovery (%)		Jaggery yield (tha ⁻¹)	
	2017-18	2018-19	2017-18	2018-19
Crop establishment techniques (M)				
M ₁ : Conventional method	8.77	8.74	9.02	8.60
M ₂ : Bud chip seedling at 90cm x 60 cm	9.08	8.81	9.86	9.28
M ₃ : Bud chip seedling at 120cm x 60 cm	9.12	9.05	11.23	10.74
SEm±	0.18	0.13	0.22	0.20
CD (P=0.05)	NS	NS	0.86	0.80
Integrated nutrient management (F)				
F ₁ : 100% RDF	8.56	8.36	8.77	8.27
F ₂ : 100% RDF + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	9.24	9.12	10.67	10.13
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	9.22	9.10	10.51	9.98
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	8.98	8.90	10.18	9.68
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	8.96	8.85	10.10	9.58
SEm±	0.12	0.09	0.11	0.13
CD (P=0.05)	0.35	0.28	0.33	0.38
Interaction (M X F)				
SEm±	0.21	0.17	0.20	0.24
CD (P=0.05)	NS	NS	NS	NS

Note: DAP: Days after planting; RDF: Recommended dose of fertilizer; GM: Green manuring; VC: Vermicompost; EC: Enriched compost; BF: Biofertilizers; SEm±: Standard error of mean; CD: Critical difference, NS: Non significant

Interaction effect

The interaction effect between crop establishment techniques and integrated nutrient management on jaggery recovery (%) was found to be non-significant during both the years.

4.4.2 Jaggery yield (t ha^{-1})

Effect of crop establishment techniques

The jaggery yield was greatly influenced by different crop establishment techniques during both the years. Data presented in Table 4.18 clearly indicated that among the crop establishment techniques, planting of bud chip seedling at 120 cm x 60 cm (M_3) recorded significantly higher jaggery yield (11.23 and 10.74 t ha^{-1}) over the planting of bud chip seedling at 90 cm x 60 (M_2) (9.86 and 9.28 t ha^{-1}) as well as conventional method of planting (M_1) (9.02 and 8.60 t ha^{-1}) for 1st and 2nd year, respectively. But M_1 and M_2 were at par in effect during both the years. The significant variation in cane yield and jaggery recovery (%) resulted in significant variation in jaggery yield under different crop establishment techniques. The production of more amount cane yield as well as jaggery recovery (%) under the planting of bud chip seedling at 120 cm x 60 cm (M_3) was responsible for production of more jaggery yield.

Effect of integrated nutrient management

The integrated nutrient management practices exhibited significant variation in jaggery yield during both the years of experimentation. The application of 100% RDF + green manuring of cowpea + vermicompost @ 1 t ha^{-1} + biofertilizers @ 10 kg ha^{-1} (F_2) recorded significantly higher jaggery yield (10.67 and 10.13 t ha^{-1}) which was at par with 100% RDF + enriched compost @ 1 t ha^{-1} + green manuring of cowpea (F_3) (10.51 and 9.98 t ha^{-1}), but superior to the treatments receiving 75% RDF + FYM @ 5 t ha^{-1} + vermicompost @ 1 t ha^{-1} + green manuring of cowpea + biofertilizers @ 10 kg ha^{-1} (F_4) (10.18 and 9.68 t ha^{-1}) and 75% RDF + FYM @ 5 t ha^{-1} + enriched compost @ 1 t ha^{-1} + green manuring of cowpea (F_5) (10.10 and 9.58 t ha^{-1}) in 1st and 2nd year, respectively. Similarly, no significant difference between F_3 and F_4 as well as F_4 and F_5 was recorded during both the years. The higher cane yield coupled with more jaggery recovery (%) under the integrated supply of organic sources of nutrients, biofertilizers along with optimal dose of inorganic fertilizers was responsible for production of more jaggery yield. Shridevi and Chandrasekhar (2004) also reported significant increase in jaggery yield due to integrated supply of 100% RDF + FYM @ 25 t ha^{-1} + biofertilizers

@ 10 kg ha⁻¹ each of *Azospirillum* and PSB + micronutrients (FeSO₄ and ZnSO₄ each of @ 25 kg ha⁻¹) over 100% RDF.

Interaction effect

The interaction effect between crop establishment techniques and integrated nutrient management failed to exert any significant difference on jaggery yield during both the years.

4.5 Plant analysis

The data pertaining to nitrogen (N), phosphorous (P) and potassium (K) content in green top, cane stalk and trash and their uptake by different plant parts as affected by different crop establishment techniques and integrated nutrient management practices are presented in Table 4.19, 4.20 and 4.21 and their corresponding analyses of variance are appended in Appendix XIX, XX, XXI.

4.5.1 Nitrogen (N) content (%) and uptake (kg ha⁻¹) by different plant parts

Irrespective of treatments, a wide range of variability in N content in different plant parts of sugarcane was observed at the time of harvesting. In both the years of investigation, the concentration of N in green top portion was found comparatively more as compared to cane stalk and trash. While, the N uptake by cane stalk was much higher as compared to uptake by cane stalk and trash.

4.5.1.1 N content in green top (%)

Effect of crop establishment techniques

Data regarding N content in green top was not affected by different crop establishment techniques during both the years. Though non-significant, comparatively higher N content in green top (0.98 and 0.95%) was recorded under the planting of bud chip seedling at 120 cm x 60 cm (M₃) followed by planting of bud chip seedling at 90 cm x 60 cm (M₂) (0.97 and 0.94%) and conventional method of planting (M₁) (0.95 and 0.93%) in 1st and 2nd year, respectively.

Integrated nutrient management

The different integrated nutrient management practices significantly influenced the N content in green top during both the years. The integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher N content in green top of 0.98% in 2017-18

and 0.96% in 2018-19, that were at par with the treatments receiving 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (0.98 and 0.95%), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + bio-fertilizers @ 10 kg ha⁻¹ (F₄) (0.97 and 0.94 %) and 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₅) (0.97 and 0.94%), but found superior to the application of 100% RDF (F₁) (0.94 and 0.91 %) in 1st and 2nd year, respectively.

Interaction effect

The interaction effect between crop establishment techniques and integrated nutrient management on N content in green top was found non-significant during both the years.

4.5.1.2 N content in cane stalk (%)

Effect of crop establishment techniques

The different crop establishment techniques did not show any significant effect on N content in cane stalk during both the years. But, planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded the similar values with the planting of bud chip seedling at 90 cm x 60 cm (M₂) (0.46 and 0.45%) which was comparatively higher than conventional method of planting (M₁) (0.44 and 0.44 %) in 2017-18 and 2018-19, respectively.

Integrated nutrient management

The N content in cane stalk was significantly influenced by different integrated nutrient management practices during both the years. Significantly higher N content in cane stalk of 0.47% in 2017-18 and 0.46% in 2018-19 were recorded under the integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) which was at par with the treatments comprised of 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (0.46 and 0.45%), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + bio-fertilizers @ 10 kg ha⁻¹ (F₄) (0.45 and 0.45%) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (0.45 and 0.44%), but superior to 100% RDF (F₁) (0.43 and 0.42%) in 2017-18 and 2018-19, respectively.

Table 4.19. Effect of crop establishment techniques and integrated nutrient management on nitrogen content and its uptake by plant at harvest of sugarcane

Treatments	Nitrogen content (%)						Nitrogen uptake (kg ha ⁻¹)					
	Green top		Cane stalk		Trash		Green top		Cane stalk		Trash	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Crop establishment techniques (M)												
M ₁ : Conventional method	0.95	0.93	0.44	0.44	0.51	0.48	42.45	39.44	136.74	131.52	41.41	38.26
M ₂ : Bud chip seedling at 90 cm x 60 cm	0.97	0.94	0.46	0.45	0.51	0.49	45.56	41.78	147.68	142.44	44.12	40.82
M ₃ : Bud chip seedling at 120 cm x 60 cm	0.98	0.95	0.46	0.45	0.52	0.50	47.95	44.18	172.32	167.07	49.19	45.18
SEm±	0.02	0.02	0.02	0.01	0.01	0.01	0.62	0.68	3.25	2.84	1.21	1.06
CD (P=0.05)	NS	NS	NS	NS	NS	NS	2.44	2.70	12.80	11.16	4.73	4.16
Integrated nutrient management practices (F)												
F ₁ : 100% RDF	0.94	0.91	0.43	0.42	0.50	0.46	40.32	38.58	136.18	128.93	42.30	36.16
F ₂ : 100% RDF + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	0.98	0.96	0.47	0.46	0.52	0.51	47.24	43.73	162.08	156.04	46.49	44.57
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	0.98	0.95	0.46	0.45	0.52	0.51	46.84	42.88	156.32	152.50	46.02	43.98
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	0.97	0.94	0.45	0.45	0.51	0.49	46.38	42.31	154.77	150.75	44.98	41.70
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	0.97	0.94	0.45	0.44	0.51	0.49	45.82	41.48	151.68	146.33	44.27	40.70
SEm±	0.01	0.01	0.01	0.01	0.01	0.01	0.48	0.50	2.10	1.61	0.43	0.50
CD (P=0.05)	0.02	0.02	0.02	0.02	0.01	0.02	1.41	1.48	6.12	4.68	1.24	1.46
Interaction (M x F)												
SEm±	0.01	0.01	0.01	0.01	0.01	0.01	0.84	0.88	3.64	2.78	0.74	0.86
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: DAP: Days after planting; RDF: Recommended dose of fertilizer; GM: Green manuring; VC: Vermicompost; EC: Enriched compost; BF: Biofertilizers; SEm±: Standard error of mean; CD: Critical difference, NS: Non significant

Interaction effect

The N content in cane stalk remained unaffected due to interaction between crop establishment techniques and integrated nutrient management during both the years.

4.5.1.3 N content in trash (%)

Effect of crop establishment techniques

Data in respect of N content in trash was not significantly influenced by different crop establishment techniques during both the years. But, the planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded comparatively higher N content in trash (0.52 and 0.50 %) followed by planting of bud chip seedling at 90 cm x 60 cm (M₂) (0.51 and 0.49%) and conventional method of planting (M₁) (0.51 and 0.48%) in 1st and 2nd year, respectively.

Integrated nutrient management

Significant variation in N content in trash was recorded due to different integrated nutrient management practices during both the years. The integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher N content in trash (0.52 and 0.51%) which was at par with the treatments receiving 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (0.52 and 0.51%) followed by application of 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) (0.51 and 0.49%) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (0.51 and 0.49%) but superior to the 100% RDF through inorganic fertilizers (F₁) (0.50 and 0.46%) in 1st and 2nd year, respectively.

Apart from nutrient supplied from inorganic sources, the slow and adequate release of nutrients from the organic sources such as vermicompost, FYM, enriched compost *etc.* might have helped in maintenance of higher concentration of nutrients throughout the crop growing period under different integrated nutrient management practices. Besides this, addition of biofertilizers like *Azotobacter* and presence of microbes in enriched compost helped in production of some biochemical substances such as protein, amino acids that increased the availability of nutrients to crop under integrated nutrients management. The significant variation in nitrogen

content in sugarcane due to different integrated nutrient management practices was also reported by Soomro *et al.* (2013).

Interaction effect

The interaction effect between crop establishment techniques and integrated nutrient management on N content in trash was found to be non-significant during both the years.

4.5.1.1.1 N uptake by green top (kg ha^{-1})

Effect of crop establishment techniques

Nitrogen (N) uptake by green top was significantly influenced by different crop establishment techniques during both the years. Significantly higher N uptake by green top was recorded under the planting of bud chip seedling at 120 cm x 60 cm (M_3) (47.95 and 44.18 kg ha^{-1}) which was at par with planting of bud chip seedling at 90 cm x 60 cm (M_2) (45.56 and 41.78 kg ha^{-1}) but superior to the conventional method (M_1) (42.45 and 39.44 kg ha^{-1}) during 2017-18 and 2018-19, respectively. However, M_2 was superior to M_1 during 2017-18, while, it was at par with M_1 during 2018-19. The variation in nitrogen content in green top portion and their dry matter production under different crop established techniques resulted variable outcome in nitrogen uptake during both the years.

Integrated nutrient management

The different integrated nutrient management treatments showed significant difference in nitrogen (N) uptake by green top during both the years. The integrated application of 100% RDF + vermicompost @ 1 t ha^{-1} + green manuring of cowpea + biofertilizers @ 10 kg ha^{-1} (F_2) recorded significantly higher N uptake (47.24 and 43.73 kg ha^{-1}) which was at par with treatments receiving 100% RDF + enriched compost @ 1 t ha^{-1} + green manuring of cowpea (F_3) (46.84 and 42.88 kg ha^{-1}), 75% RDF + FYM @ 5 t ha^{-1} + vermicompost @ 1 t ha^{-1} + green manuring of cowpea + biofertilizers @ 10 kg ha^{-1} (F_4) (46.38 and 42.31 kg ha^{-1}), but superior to 75% RDF + FYM @ 5 t ha^{-1} + enriched compost @ 1 t ha^{-1} + green manuring of cowpea (F_5) (45.82 and 41.48 kg ha^{-1}) during 2017-18 and 2018-19, respectively. The lowest N uptake by green top (40.32 kg ha^{-1} during 2017-18 and 38.58 kg ha^{-1} during 2018-19) was recorded under the treatment receiving 100% RDF.

Interaction effect

The interaction effect between crop establishment techniques and integrated nutrient management on N uptake by green top was found non-significant during both the years.

4.5.1.1.2 N uptake by cane stalk (kg ha^{-1})

Effect of crop establishment techniques

Nitrogen (N) uptake by cane stalk differed significantly by different crop establishment techniques during both the years. The planting of bud chip seedling at 120 cm x 60 cm (M_3) recorded significantly higher N uptake by cane stalk (172.32 and 167.07 kg ha^{-1}) as compared to the planting of bud chip seedling at 90 cm x 60 cm (M_2) (147.68 and 142.44 kg ha^{-1}) as well as conventional method (M_1) (136.74 and 131.52 kg ha^{-1}) in 1st and 2nd year, respectively.

Integrated nutrient management

Application of different integrated nutrient management practices significantly influenced the nitrogen (N) uptake by cane stalk during both the years. Significantly higher N uptake of 162.08 kg ha^{-1} in 2017-18 and 156.04 kg ha^{-1} in 2018-19 were obtained under the application of 100% RDF + vermicompost @ 1 t ha^{-1} + green manuring of cowpea + biofertilizers @ 10 kg ha^{-1} (F_2) which was at par with 100% RDF + enriched compost @ 1 t ha^{-1} + green manuring of cowpea (F_3) (156.32 and 152.50 kg ha^{-1}), but superior to treatment receiving 75% RDF + FYM @ 5 t ha^{-1} + vermicompost @ 1 t ha^{-1} + green manuring of cowpea + bio-fertilizers @ 10 kg ha^{-1} (F_4) (154.77 and 150.75 kg ha^{-1}) and 75% RDF + FYM @ 5 t ha^{-1} + enriched compost @ 1 t ha^{-1} + green manuring of cowpea (F_5) (151.68 and 146.33 kg ha^{-1}) in 1st and 2nd year, respectively. On other hand, significantly lower N uptake by cane stalk was recorded under the treatment receiving 100% RDF (F_1) (136.18 and 128.93 kg ha^{-1}) in 1st and 2nd year, respectively.

Interaction effect

Nitrogen uptake by cane stalk remained unaffected due to interaction effect between crop establishment techniques and integrated nutrient management during both the years.

4.5.1.1.1 N uptake by trash (kg ha⁻¹)

Effect of crop establishment techniques

Nitrogen uptake by trash was significantly influenced by different crop establishment techniques during both the years. Planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded the maximum N uptake by trash (49.19 and 45.18 kg ha⁻¹) which was significantly higher than the planting of bud chip seedling at 90 cm x 60 cm (M₂) (44.12 and 40.82 kg ha⁻¹) and conventional method (M₁) (41.41 and 38.26 kg ha⁻¹) during 2017-18 and 2018-19, respectively. But the effect of both M₁ and M₂ was at par with each other during both the years.

The nutrient uptake by plant is directly related to dry matter production as well as nutrient content in plants. The more dry matter production by different parts *viz.*, green top, cane stalk and trash due to more number of canes per unit area along with increase in N content resulted in significant enhancement in N uptake by the respective plant parts under the planting of bud chip seedling at 120 cm x 60 cm (M₃).

Integrated nutrient management

The different integrated nutrient management treatments showed significant variation in N uptake by trash during both the years. Among the treatments, the integrated application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher N uptake by trash (46.49 and 44.57 kg ha⁻¹) which was at par with treatment receiving 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (46.02 and 43.98 kg ha⁻¹), but found superior to the application of 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + bio-fertilizers @ 10 kg ha⁻¹ (F₄) (44.98 and 41.70 kg ha⁻¹) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (44.27 and 40.70 kg ha⁻¹) in 1st and 2nd year, respectively. Whereas, significantly lower values of 42.30 kg ha⁻¹ during 1st year and 36.16 kg ha⁻¹ during 2nd year were obtained under 100% RDF. However, the effect of F₃ was at par with F₄ during 2017-18, while significant difference between two treatments was observed during 2018-19. Moreover, no significant difference was observed between the treatments receiving different nutrient sources with 75% RDF *i.e.* F₄ and F₅ during both the years.

The greater availability of nitrogen to the crop from different sources increased the dry matter accumulation as well as nutrient content in different plant parts

viz., green top, cane stalk and trash which might have helped in increase in N uptake by plant under the treatment receiving 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹. Manimaran and Kalyanasundaram (2006) also reported greater availability of nitrogen to plant as well as more nitrogen uptake by plant through integration of inorganic nutrients, biofertilizers and green manuring of sun hemp.

Interaction effect

No significant interaction effect between crop establishment techniques and integrated nutrient management on N uptake by trash was found during both the years.

4.5.2 Phosphorous (P) content (%) and uptake (kg ha⁻¹) by different plant parts

4.5.2.1 P content in green top (%)

Effect of crop establishment techniques

The different crop establishment techniques did not exhibit any significant difference on P content in green top during both the years. Nevertheless, the planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded comparatively higher P content (0.088 and 0.086%) than planting of bud chip seedling at 90 cm x 60 cm (M₂) (0.086 and 0.085%) and conventional method of planting (M₁) (0.084 and 0.083%) in 2017-18 and 2018-19, respectively.

Integrated nutrient management

The phosphorous content in green top was not significantly influenced by different integrated nutrient management practices during both the years. Yet, comparatively higher P content in green top of 0.088% in 2017-18 and 0.087% in 2018-19 was recorded due to application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) as compared to all other treatments. Whereas, the treatment receiving 100% RDF (F₁) recorded the minimum values (0.084 and 0.082%) in 1st and 2nd year, respectively.

Interaction effect

The interaction effect between crop establishment techniques and integrated nutrient management on P content in green top was found non-significant during both the years.

Table 4.20. Effect of crop establishment techniques and integrated nutrient management on phosphorous content and its uptake by plant at harvest of sugarcane

Treatments	Phosphorous content (%)						Phosphorous uptake (kg ha ⁻¹)					
	Green top		Cane stalk		Trash		Green top		Cane stalk		Trash	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Crop establishment techniques (M)												
M ₁ : Conventional method	0.084	0.083	0.078	0.077	0.076	0.075	3.75	3.52	24.24	23.11	6.18	5.98
M ₂ : Bud chip seedling at 90 cm x 60 cm	0.086	0.085	0.079	0.078	0.077	0.076	4.04	3.78	25.36	24.88	6.66	6.33
M ₃ : Bud chip seedling at 120 cm x 60 cm	0.088	0.086	0.080	0.078	0.077	0.076	4.31	4.02	29.95	28.95	7.28	6.86
SEm±	0.002	0.001	0.001	0.002	0.002	0.001	0.11	0.11	0.97	1.01	0.21	0.20
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.42	0.41	3.82	4.03	0.84	0.80
Integrated management Practices (F)												
F ₁ : 100% RDF	0.084	0.082	0.077	0.076	0.075	0.073	3.58	3.48	23.68	23.33	6.35	5.74
F ₂ : 100% RDF + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	0.088	0.087	0.081	0.079	0.078	0.077	4.24	3.96	27.94	26.80	6.97	6.73
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	0.087	0.087	0.080	0.078	0.078	0.077	4.16	3.93	27.28	26.43	6.90	6.63
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	0.086	0.084	0.079	0.078	0.077	0.075	4.11	3.78	27.17	26.13	6.79	6.38
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	0.086	0.084	0.079	0.077	0.076	0.075	4.06	3.71	26.52	25.61	6.60	6.36
SEm±	0.001	0.001	0.001	0.001	0.001	0.001	0.06	0.09	0.51	0.56	0.16	0.14
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.18	0.25	1.48	1.67	0.47	0.42
Interaction (M x F)												
SEm±	0.002	0.001	0.001	0.002	0.002	0.001	0.11	0.15	0.88	0.98	0.27	0.25
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: DAP: Days after planting; RDF: Recommended dose of fertilizer; GM: green manuring; VC: vermicompost; EC: Enriched compost; BF: Biofertilizers; SEm±: Standard error of mean; CD: Critical difference, NS: Non significant

4.5.2.2 P content in cane stalk (%)

Effect of crop establishment techniques

The phosphorous content in cane stalk did not differ due to different crop establishment techniques during both the years. But, planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded comparatively higher P content (0.080 and 0.078%) than planting of bud chip seedling at 90 cm x 60 cm (M₂) (0.079 and 0.078%) and conventional method of planting (M₁) (0.078 and 0.077%) in 2017-18 and 2018-19, respectively.

Integrated nutrient management

The different integrated nutrient management practices did not show any significant effect on the P content in cane stalk during both the years. However, 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded comparatively higher P content (0.081 and 0.079) as compared to all other treatments and the treatment receiving 100% RDF recorded the minimum P content of 0.077% in 1st year and 0.076% in 2nd year.

Interaction effect

No significant effect on P content in cane stalk was observed due the interaction between crop establishment techniques and integrated nutrient management during both the years.

4.5.2.2 P content in trash (%)

Effect of crop establishment techniques

The phosphorous content in trash was not significantly influenced by different crop establishment techniques during both the years. But, the planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded the similar values (0.077 and 0.076%) with the planting of bud chip seedling at 90 cm x 60 cm (M₂) which was slightly higher than conventional method of planting (M₁) (0.076 and 0.075%) in 2017-18 and 2018-19, respectively.

Integrated nutrient management

The phosphorous content in trash was not significantly affected due to different integrated nutrient management practices during both the years. Yet, the application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea +

biofertilizers @ 10 kg ha⁻¹ (F₂) recorded the similar values (0.078 and 0.077%) with the application of 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) during 1st and 2nd year, respectively which was comparatively higher than the rest of the treatments. The treatment receiving 100% RDF (F₁) recorded the minimum P content of 0.075% in 1st year and 0.073% in 2nd year.

Interaction effect

The interaction effect between crop establishment techniques and integrated nutrient management on P content in trash was found non-significant during both the years.

4.5.2.1.1 P uptake by green top (kg ha⁻¹)

Effect of crop establishment techniques

The different crop establishment techniques significantly affected the phosphorous (P) uptake by green top during both the years. Significantly higher P uptake of 4.31 kg ha⁻¹ during 2017-18 and 4.02 kg ha⁻¹ during 2018-19 were recorded due to planting of bud chip seedling at 120 cm x 60 cm (M₃) as compared to conventional method (M₁) (3.75 and 3.52 kg ha⁻¹) but at par with planting of bud chip seedling at 90 cm x 60 cm (M₂) (4.04 and 3.78 kg ha⁻¹) during 1st and 2nd year, respectively. However, the effect of M₁ and M₂ was at par with each other during both the years.

Effect of integrated nutrient management

Different integrated nutrient management practices significantly influenced the phosphorous (P) uptake by green top during both the years. Application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher phosphorous uptake by green top (4.24 and 3.96 kg ha⁻¹) which was at par with application of 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (4.16 and 3.93 kg ha⁻¹), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + bio-fertilizers @ 10 kg ha⁻¹ (F₄) (4.11 and 3.78 kg ha⁻¹) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (4.06 and 3.71 kg ha⁻¹) in 1st and 2nd year, respectively. The treatment receiving 100% RDF through inorganic fertilizers (F₁) registered the lowest phosphorous uptake of 3.58 kg ha⁻¹ in 1st year and 3.48 kg ha⁻¹ in 2nd year.

Interaction effect

The interaction effect between crop establishment techniques and integrated nutrient management on P uptake by green top was found non-significant during both the years.

4.5.2.1.2 P uptake by cane stalk (kg ha^{-1})

Effect of crop establishment techniques

Phosphorous (P) uptake by cane stalk was significantly influenced by different crop establishment techniques during both the years. The planting of bud chip seedling at 120 cm x 60 cm (M_3) recorded significantly higher P uptake (29.95 and 28.95 kg ha^{-1}) as compared to planting of bud chip seedling at 90 cm x 60 cm (M_2) (25.36 and 24.88 kg ha^{-1}) and conventional method (M_1) (24.24 and 23.11 kg ha^{-1}) during 2017-18 and 2018-19, respectively. But both M_1 and M_2 was at par with each other in terms of P uptake by cane stalk during both the years.

Effect of integrated nutrient management

Various integrated nutrient management practices significantly influenced the phosphorous (P) uptake by cane stalk during both the years. Application of 100% RDF + vermicompost @ 1 t ha^{-1} + green manuring of cowpea + biofertilizers @ 10 kg ha^{-1} (F_2) registered significantly higher P uptake (27.94 and 26.80 kg ha^{-1}) which was at par with all the treatments receiving both organic as well as inorganic sources of nutrients *viz.*, 100% RDF + enriched compost @ 1 t ha^{-1} + green manuring of cowpea (F_3) (27.28 and 26.43 kg ha^{-1}), 75% RDF + FYM @ 5 t ha^{-1} + vermicompost @ 1 t ha^{-1} + green manuring of cowpea + bio-fertilizers @ 10 kg ha^{-1} (F_4) (27.17 and 26.13 kg ha^{-1}) and 75% RDF + FYM @ 5 t ha^{-1} + enriched compost @ 1 t ha^{-1} + green manuring of cowpea (F_5) (26.52 and 25.61 kg ha^{-1}) in 1st and 2nd year, respectively. On the other hand, sole application inorganic fertilizers *i.e.* 100% RDF (F_1) registered the lowest P uptake of 23.68 kg ha^{-1} in 1st year and 23.33 kg ha^{-1} in 2nd year.

Interaction effect

No significant difference on P uptake by cane stalk was observed due to interaction effect between crop establishment techniques and integrated nutrient management during both the years.

4.5.2.1.3 P uptake by trash (kg ha⁻¹)

Effect of crop establishment techniques

The different crop establishment techniques exerted significant variation in phosphorous (P) uptake by trash during both the years. Significantly higher P uptake of 7.28 kg ha⁻¹ during 2017-18 and 6.86 kg ha⁻¹ during 2018-19 were recorded under the planting of bud chip seedling at 120 cm x 60 cm (M₃) which was at par with planting of bud chip seedling at 90 cm x 60 cm (M₂) (6.66 and 6.33 kg ha⁻¹) but superior to the conventional method (M₁) (6.18 and 5.98 kg ha⁻¹) in 1st and 2nd year, respectively. Besides this, both M₂ and M₁ were at par with each other in terms of phosphorous uptake by trash during both the years.

Effect of integrated nutrient management

Different integrated nutrient management practices significantly influenced the P uptake by trash during both the years. Application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher amount of P uptake (6.97 and 6.73 kg ha⁻¹) that was at par with all the treatments receiving different sources of nutrients *viz.*, 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (6.90 and 6.63 kg ha⁻¹), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + bio-fertilizers @ 10 kg ha⁻¹ (F₄) (6.79 and 6.38 kg ha⁻¹) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (6.60 and 6.36 kg ha⁻¹) in 1st and 2nd year, respectively. But, the phosphorous uptake by trash under 100% RDF through inorganic fertilizers (F₁) (6.35 kg ha⁻¹ in 1st year and 5.74 kg ha⁻¹ in 2nd year) was at par with both F₄ and F₅ during 2017-18 and differed from each other during 2018-19. The variation in nutrient content in trash as well as their dry matter production in individual year might be responsible for variable results.

Interaction effect

The interaction effect between crop establishment techniques and integrated nutrient management on phosphorous (P) uptake by trash was found non-significant during both the years.

4.5.3 K content (%) and uptake (kg ha^{-1}) by different plant parts

4.5.3.1 K content in green top (%)

Effect of crop establishment techniques

Data on potassium content in green top revealed non-significant effect due to different crop establishment techniques in both the years. But, planting of bud chip seedling at 120 cm x 60 cm (M_3) recorded comparatively higher K content (0.91 and 0.88%) than planting of bud chip seedling at 90 cm x 60 cm (M_2) (0.89 and 0.86 %) and conventional method of planting (M_1) (0.87 and 0.84%) in 1st and 2nd year, respectively.

Effect of integrated nutrient management

Potassium content in green top was not significantly influenced by different integrated nutrient management during both the years. Yet, the treatments comprised of different integrated nutrient sources recorded comparatively higher K content in green top as compared to 100% RDF (F_1) during both the years. Among the treatments, 100% RDF + vermicompost @ 1 t ha^{-1} + green manuring of cowpea + biofertilizers @ 10 kg ha^{-1} (F_2) recorded comparatively higher K content of 0.91% in 2017-18 and 0.88% in 2018-19 than all other treatments. The treatment receiving 100% RDF (F_1) registered the lowest K content of 0.87% in 1st year and 0.84% in 2nd year.

Interaction effect

No significant interaction effect was found between crop establishment techniques and integrated nutrient management on K content in green top during both the years.

4.5.3.2 K content in cane stalk (%)

Effect of crop establishment techniques

The potassium content in cane stalk remained unaffected due to different crop establishment techniques in both the years. Nevertheless, planting of bud chip seedling at 120 cm x 60 cm (M_3) recorded similar values with the planting of bud chip seedling at 90 cm x 60 cm (M_2) (0.58 and 0.57%) which was comparatively higher than conventional method of planting (M_1) (0.57 and 0.56%) in 1st and 2nd year, respectively.

Table 4.21. Effect of crop establishment techniques and integrated nutrient management on potassium content and its uptake by plant at harvest

Treatments	Potassium content (%)						Potassium uptake (kg/ha)					
	Green top		Cane stalk		Trash		Green top		Cane stalk		Trash	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Crop establishment technique (M)												
M ₁ : Conventional method	0.87	0.84	0.57	0.56	0.33	0.32	38.88	35.58	177.14	172.67	26.86	25.36
M ₂ : Bud chip seedling at 90 cm x 60 cm	0.89	0.86	0.58	0.57	0.34	0.33	41.80	38.21	190.22	186.77	29.31	27.48
M ₃ : Bud chip seedling at 120 cm x 60 cm	0.91	0.88	0.58	0.57	0.34	0.33	44.51	40.92	214.27	205.84	32.16	29.80
SEm±	0.02	0.03	0.02	0.02	0.02	0.01	1.07	1.03	4.32	4.41	0.84	0.74
CD (P=0.05)	NS	NS	NS	NS	NS	NS	4.17	4.02	16.98	17.32	3.28	2.90
Integrated nutrient management practices (F)												
F ₁ : 100% RDF	0.87	0.84	0.55	0.54	0.32	0.31	37.29	35.61	173.78	165.76	27.04	24.37
F ₂ : 100% RDF + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	0.91	0.88	0.59	0.59	0.35	0.34	43.87	40.09	204.46	199.32	31.29	29.72
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	0.90	0.87	0.59	0.58	0.35	0.33	43.02	39.27	201.77	197.85	30.98	28.61
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	0.89	0.86	0.58	0.57	0.34	0.33	42.55	38.71	195.68	190.95	29.63	27.88
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	0.88	0.85	0.57	0.56	0.33	0.32	41.90	37.51	193.88	187.52	28.26	27.14
SEm±	0.01	0.01	0.01	0.01	0.01	0.01	0.63	0.70	2.38	2.20	0.39	0.46
CD (P=0.05)	NS	NS	0.02	0.02	NS	NS	1.85	2.05	6.94	6.41	1.13	1.34
Interaction (M x F)												
SEm±	0.02	0.02	NS	0.01	0.01	0.01	1.10	1.22	4.12	3.80	0.67	0.80
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: DAP: Days after planting; RDF: Recommended dose of fertilizer; GM: green manuring; VC: vermicompost; EC: Enriched compost; BF: Biofertilizers; SEM±: Standard error of mean; CD: Critical difference, NS: Non significant

Effect of integrated nutrient management

Application of different integrated nutrient management practices significantly influenced the potassium content in cane stalk during both the years. Among the treatments, the integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher K content (0.59 and 0.59%) which was at par with the treatments receiving 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (0.59 and 0.58%), 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + bio-fertilizers @ 10 kg ha⁻¹ (F₄) (0.58 and 0.57%) and 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (0.57 and 0.56%) during 2017-18, but at par with F₃ and F₄ only during 2018-19. Whereas, the K content in cane stalk under 100% RDF (F₁) recorded the lowest values (0.55 and 0.54%) which was at par with the treatment receiving 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) in 1st and 2nd year, respectively.

Interaction effect

No significant interaction effect on K content in cane stalk was observed between crop establishment techniques and integrated nutrient management during both the years.

4.5.3.1 K content in trash (%)

Effect of crop establishment techniques

The different crop establishment techniques did not exert any significant effect on K content in trash during both the years. Although, planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded similar values (0.34 and 0.33%) with the planting of bud chip seedling at 90 cm x 60 cm (M₂) which was comparatively higher than conventional method (M₁) (0.33 and 0.32%) in 1st and 2nd year, respectively.

Effect of integrated nutrient management

Application of various integrated nutrient management practices failed to reveal any significant effect on K content in trash during both the years. All the treatments comprised of integrated nutrient sources recorded comparatively higher K content in trash as compared to sole inorganic fertilizers. The application of 100% RDF + green manuring of cowpea + vermicompost @ 1 t ha⁻¹ + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded comparatively higher values (0.35 and 0.34%) than rest of the treatments

during both the years. The lowest K content in trash (0.32 and 0.31%) was obtained under the treatment receiving 100% RDF (F₁) during both the years.

Interaction effect

The interaction effect between crop establishment techniques and integrated nutrient management on potassium (K) content in trash was found to be non-significant during both the years.

4.5.3.1.1 Potassium (K) uptake by green top (kg ha⁻¹)

Effect of crop establishment techniques

The potassium uptake by green top was significantly affected due to different crop establishment techniques in both the years. Significantly higher K uptake by green top (44.51 and 40.92 kg ha⁻¹) was recorded under the planting of bud chip seedling at 120 cm x 60 cm (M₃) which was at par with planting of bud chip seedling at 90 cm x 60 cm (M₂) (41.80 and 38.21 kg ha⁻¹), but superior to the conventional method (M₁) (38.88 and 35.58 kg ha⁻¹) in 1st and 2nd year, respectively. However, the effect of M₁ and M₂ was at par in terms of K uptake by green top during both the years.

Effect of integrated nutrient management

The integrated nutrient management practices significantly influenced the potassium uptake by green top in both the years. The integrated supply of 100% RDF + green manuring of cowpea + vermicompost @ 1 t ha⁻¹ + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher K uptake (43.87 and 40.09 kg ha⁻¹) which was at par with the treatments receiving 100 % RDF + green manuring of cowpea + enriched compost @ 1 t ha⁻¹ (F₃) (43.02 and 39.27 kg ha⁻¹) and 75% RDF + FYM @ 5 t ha⁻¹ + green manuring of cowpea + vermicompost @ 1 t ha⁻¹ + biofertilizers @ 10 kg ha⁻¹ (F₄) (42.55 and 38.71 kg ha⁻¹), but significantly higher over the treatment receiving 75% RDF + FYM @ 5 t ha⁻¹ + green manuring of cowpea + enriched compost @ 1 t ha⁻¹ (F₅) (41.90 and 37.51 kg ha⁻¹) during 2017-18 and 2018-19, respectively. But, F₃, F₄ and F₅ did not differ from each other during both the years. Whereas, the lowest values of 37.29 kg ha⁻¹ during 2017-18 and 35.61 kg ha⁻¹ during 2018-19 were obtained under the application of 100% RDF.

Interaction effect

The interaction between crop establishment techniques and integrated nutrient management failed to reveal any significant effect on K uptake by green top during both the years.

4.5.3.1.1 Potassium (K) uptake by cane stalk (kg ha^{-1})

Effect of crop establishment techniques

The potassium uptake by cane stalk significantly differed due to different crop establishment techniques in both the years. Planting of bud chip seedling at 120 cm x 60 cm (M_3) recorded significantly higher K uptake (214.27 and $205.84 \text{ kg ha}^{-1}$) as compared to planting of bud chip seedling at 90 cm x 60 cm (M_2) (190.22 and $186.77 \text{ kg ha}^{-1}$) and conventional method (M_1) (177.14 and $172.67 \text{ kg ha}^{-1}$) during 2017-18 and 2018-19, respectively. But, the effect of M_1 and M_2 was at par in terms of K uptake by cane stalk during both the years.

Effect of integrated nutrient management

The different integrated nutrient management practices showed significant variation in potassium uptake by cane stalk in both the years. The integrated supply of 100% RDF + green manuring of cowpea + vermicompost @ 1 t ha^{-1} + biofertilizers @ 10 kg ha^{-1} (F_2) recorded significantly higher K uptake (204.46 and $199.32 \text{ kg ha}^{-1}$) which was at par with 100 % RDF + green manuring of cowpea + enriched compost @ 1 t ha^{-1} (F_3) (201.77 and $197.85 \text{ kg ha}^{-1}$), but found to be superior to the application of 75% RDF + FYM @ 5 t ha^{-1} + green manuring of cowpea + vermicompost @ 1 t ha^{-1} + biofertilizers @ 10 kg ha^{-1} (F_4) (195.68 and $190.95 \text{ kg ha}^{-1}$) and 75% RDF + FYM @ 5 t ha^{-1} + green manuring of cowpea + enriched compost @ 1 t ha^{-1} (F_5) (193.88 and $187.52 \text{ kg ha}^{-1}$) during 2017-18 and 2018-19 respectively. But F_3 was also superior over F_4 and F_5 during 2018-19, while at par with F_4 during 2017-18. both the years, significantly lower uptake of K in cane stalk (173.78 and $165.76 \text{ kg ha}^{-1}$) was obtained under 100% RDF (F_1).

Interaction effect

The interaction between crop establishment techniques and integrated nutrient management practices failed to reveal any significant effect on K uptake by cane stalk during both the years.

4.5.3.1.1 Potassium (K) uptake by trash (kg ha^{-1})

Effect of crop establishment techniques

The potassium uptake by trash was significantly influenced by different integrated nutrient management practices in both the years. The planting of bud chip seedling at 120 cm x 60 cm (M_3) recorded significantly higher K uptake (32.16 and 29.80 kg ha^{-1}) than the conventional method (M_1) (26.86 and 25.36 kg ha^{-1}) which was at par with planting of bud chip seedling at 90 cm x 60 cm (M_2) (29.31 and 27.48 kg ha^{-1}) during 2017-18 and 2018-19, respectively. But, the effect of M_1 and M_2 was found to be at par in terms of K uptake by trash during both the years.

Experimental findings clearly revealed that different crop establishment techniques resulted in variation in K uptake by different plant parts (cane stalk, green top and trash) in both the years. The significant variation in terms of dry matter production by cane stalk, green top and trash resulted in significant variation in nutrient uptake under different crop establishment techniques. The production of more plant biomass and higher K content in different plant parts under the planting of bud chip seedling at 120 cm x 60 cm (M_3) resulted in significantly higher K uptake as compared to other crop establishment techniques.

Effect of integrated nutrient management

The integrated nutrient management practices significantly influenced the potassium uptake by trash in both the years. Significantly higher K uptake by trash was also obtained under the integrated supply of 100% RDF + green manuring of cowpea + vermicompost @ 1 t ha^{-1} + biofertilizers @ 10 kg ha^{-1} (F_2) (31.29 kg ha^{-1} , 29.72 kg ha^{-1}) which was at par with the treatments receiving 100 % RDF + green manuring of cowpea + enriched compost @ 1 t ha^{-1} (F_3) (30.98 and 28.61 kg ha^{-1}), but significantly superior to the application of 75% RDF + FYM @ 5 t ha^{-1} + green manuring of cowpea + vermicompost @ 1 t ha^{-1} + biofertilizers @ 10 kg ha^{-1} (F_4) (29.63 and 27.88 kg ha^{-1}) and 75% RDF + FYM @ 5 t ha^{-1} + green manuring of cowpea + vermicompost @ 1 t ha^{-1} + biofertilizers @ 10 kg ha^{-1} (F_5) (28.26 and 27.14 kg ha^{-1}) in 1st and 2nd year, respectively. But, both F_3 and F_4 were at par in effect during 2018-19. Besides this, no significant difference was observed between F_4 and F_5 during both the years. But, all the treatments comprised of different sources of nutrients were found to be superior to 100% RDF (F_1) (27.04 and 24.37 kg ha^{-1}) in both the years. This might be due to higher amount of K release under the integration of organic sources of nutrients

along with optimal dose of inorganic fertilizer (100% RDF) as compared to sub-optimal dose (75%). Significantly higher amount of K uptake due to incorporation of green manuring crop along with 100% RDF was also reported by More *et al.* (2009).

The significant variation in nitrogen, phosphorous and potassium uptake by green top, cane stalk, and trash was ascribed due to significant variation in dry matter production as well as more nutrient content under different integrated nutrient management practices. Irrespective of treatments, the N, P and K uptake by the cane stalk was comparatively more than that of trash and green top. The higher amount of nutrients uptake by cane stalk was associated with high dry matter production by the cane stalk as compared to trash and green top. The release of more NPK coupled with better growth as well as yield might be responsible for more NPK uptake by different plant parts under integrated nutrient management as compared to 100% RDF. The more nutrients uptake due to integration of FYM and biofertilizers along with 100% RDF over 100% RDF were also reported by Saini *et al.* (2006) and Kumar *et al.* (2015). Lakshmi *et al.* (2011) also reported that irrespective of their sources, the combined application of inorganic and organic nutrients reported significant increase in NPK uptake over 100% RDF.

Interaction effect

Potassium uptake by trash remained unaffected due to interaction effect between crop establishment techniques and integrated nutrient management during both the years.

4.6 Total nutrient uptake by plant (N, P and K) (kg ha⁻¹)

The data pertaining to total nutrient uptake by plant as affected by different crop establishment techniques and integrated nutrient management practices are presented in Table 4.22 and their corresponding analyses of variance are appended in Appendix XXII.

4.6.4.1 Total nitrogen uptake by plant (kg ha⁻¹)

Effect of crop establishment techniques

The total nitrogen (N) uptake of sugarcane plant differed significantly due to different crop establishment techniques during both the years. Planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded significantly higher total N uptake

(269.46 and 256.57 kg ha⁻¹) over the planting of bud chip seedling at 90 cm x 60 cm (M₂) (237.26 and 224.84 kg ha⁻¹) as well as conventional method of planting (M₁) (220.46 and 209.22 kg ha⁻¹) during 2017-18 and 2018-19, respectively.

Effect of integrated nutrient management

Application of different integrated nutrient management practices revealed significant variations on total nitrogen (N) uptake by plant during both the years. The integration of 100% RDF + green manuring of cowpea + vermicompost @ 1 t ha⁻¹ + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher total N uptake (255.81 and 244.34 kg ha⁻¹) which was at par with the application of 100 % RDF + green manuring of cowpea + enriched compost @ 1 t ha⁻¹ (F₃) (249.18 and 239.29 kg ha⁻¹), but found to be superior to the treatments *viz.*, 75% RDF + FYM @ 5 t ha⁻¹ + green manuring of cowpea + vermicompost @ 1 t ha⁻¹ + biofertilizers @ 10 kg ha⁻¹ (F₄) (246.13 and 234.76 kg ha⁻¹) and 75% RDF + FYM @ 5 t ha⁻¹ + green manuring of cowpea + enriched compost @ 1 t ha⁻¹ (F₅) (241.87 and 228.51 kg ha⁻¹) in 1st and 2nd year, respectively. But F₃ and F₄ as well as F₄ and F₅ was at par with each other during both the years. All the treatments comprised of integrated nutrient management recorded significantly higher values as compared to 100% RDF (218.80 and 203.67 kg ha⁻¹) in 1st and 2nd year, respectively

Interaction effect

The interaction between crop establishment techniques and integrated nutrient management failed to reveal any significant effect on total nitrogen uptake during both the years of investigation.

4.6.4.2 Total phosphorous (P) uptake by plant (kg ha⁻¹)

Effect of crop establishment techniques

The total phosphorous uptake by plant differed significantly due to different crop establishment techniques during both the years. Planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded significantly higher uptake (41.54 and 39.67 kg ha⁻¹) which was found to be superior to the planting of bud chip seedling at 90 cm x 60 cm (M₂) (36.06 and 35.44 kg ha⁻¹) as well as conventional method of planting (M₁) (34.17 and 33.62 kg ha⁻¹) during 2017-18 and 2018-19, respectively.

Table 4.22. Effect of crop establishment techniques and integrated nutrient management on total nutrient uptake by plant at harvest of sugarcane

Treatments	Nitrogen (kg ha ⁻¹)		Phosphorous (kg ha ⁻¹)		Potassium (kg ha ⁻¹)	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Crop establishment techniques (M)						
M ₁ :Conventional method	220.46	209.22	34.17	33.62	242.88	233.61
M ₂ : Bud chip seedling at 90 cm x 60 cm	237.26	224.84	36.06	35.44	261.33	252.46
M ₃ :Bud chip seedling at 120 cm x 60 cm	269.46	256.57	41.54	39.67	290.94	276.56
SEm±	7.71	7.80	1.08	0.98	4.90	5.80
CD (P=0.05)	30.29	30.62	4.27	3.77	19.25	22.76
Integrated nutrient management practices (F)						
F ₁ : 100% RDF	218.80	203.67	33.61	32.98	238.11	225.74
F ₂ : 100% RDF + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	255.81	244.34	39.15	37.91	279.62	269.13
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	249.18	239.29	38.34	37.04	275.77	265.73
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	246.13	234.76	38.07	36.73	267.86	257.54
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	241.87	228.51	37.18	36.34	264.04	253.17
SEm±	2.29	2.58	0.51	0.43	1.86	1.97
CD (P=0.05)	6.67	7.52	1.48	1.26	5.42	5.76
Interaction (M x F)						
SEm±	3.96	4.46	0.88	0.75	3.22	3.42
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Note: DAP: Days after planting; RDF: Recommended dose of fertilizer; GM: green manuring; VC: vermicompost; EC: Enriched compost; BF: Biofertilizers; SEM±: Standard error of mean; CD: Critical difference, NS: Non significant

Effect of integrated nutrient management

The various integrated nutrient management practices revealed significant differences on total phosphorous uptake by plant during both the years. The application of 100% RDF + green manuring of cowpea + vermicompost @ 1 t ha⁻¹ + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher P uptake (39.15 and 37.91 kg ha⁻¹) which was at par with 100 % RDF + green manuring of cowpea + enriched compost @ 1 t ha⁻¹ (F₃) (38.34 and 37.04 kg ha⁻¹), 75% RDF+ FYM @ 5 t ha⁻¹ + green manuring of cowpea + vermicompost @ 1 t ha⁻¹ + biofertilizers @ 10 kg ha⁻¹ (F₄) (38.07 and 36.73 kg ha⁻¹), but superior to 75% RDF + FYM @ 5 t ha⁻¹ + green manuring of cowpea + enriched compost @ 1 t ha⁻¹ (F₅) (37.18 and 36.34 kg ha⁻¹) during 2017-18 and 2018-19, respectively. However, F₃ was at par with F₄ and F₅ in both the years. All the above treatments resulted significantly higher total P uptake as compared to 100% RDF (33.61 and 32.98 kg ha⁻¹) during both the years.

Interaction effect

No significant difference in total phosphorous uptake was observed due to interaction between crop establishment techniques and integrated nutrient management during both the years.

4.6.4.2 Total potassium uptake by plant (kg ha⁻¹)

Effect of crop establishment techniques

The total potassium uptake by plant differed significantly due to different crop establishment techniques during both the years. The planting of bud chip seedling at 120 cm x 60 cm (M₃) recorded significantly higher total K uptake by plant (290.94 and 276.56 kg ha⁻¹) over the planting of bud chip seedling at 90 cm x 60 cm (M₂) (261.33 and 252.46 kg ha⁻¹) as well as conventional method of planting (M₁) (242.88 and 233.61 kg ha⁻¹) during 2017-18 and 2018-19, respectively. However, both M₁ and M₂ were found to be at par with each other during both the years.

The higher uptake of N, P and K by cane stalk, green top as well as trash resulted in significant increase of total nutrient uptake under the planting of bud chip seedling at 120 cm x 60 cm (M₃).

Effect of integrated nutrient management

During both the years of experimentation, various integrated nutrient management practices exhibited significant differences on total potassium uptake by

plant. The integrated application of 100% RDF + green manuring of cowpea + vermicompost @ 1 t ha⁻¹ + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher K uptake (279.62 and 269.13 kg ha⁻¹) which was at par with 100 % RDF + green manuring of cowpea + enriched compost @ 1 t ha⁻¹ (F₃) (275.77 and 265.73 kg ha⁻¹), but significantly superior to the treatments receiving 75% RDF + green manuring of cowpea + vermicompost @ 1 t ha⁻¹ + biofertilizers @ 10 kg ha⁻¹ (F₄) (267.86 and 257.54 kg ha⁻¹) and 75% RDF + FYM @ 5 t ha⁻¹ + green manuring of cowpea + enriched compost @ 1 t ha⁻¹ (F₅) (264.04 and 253.17 kg ha⁻¹) during 1st and 2nd year, respectively. No significant difference between F₄ and F₅ was observed in respect of total K uptake during both years. But, all the above treatments were found to be significantly higher over the treatment receiving 100% RDF (F₁) (238.11 kg ha⁻¹ in 2017-18 and 225.74 kg ha⁻¹ in 2018-19).

The nutrient uptake by plant was mainly governed by the amount of dry biomass production as well as nutrient status of the crop. Significantly higher uptake of total N, P and K by the crop under the integrated supply of both organic and inorganic sources of nutrients might be due to better biomass production and higher nutrient concentration in plants. Kumar *et al.* (2017) also reported significant increase in total N, P and K uptake due to integration of FYM @ 10 t ha⁻¹ and biofertilizers along with 100% RDF as compared to sole application of 100% RDF.

Interaction effect

The interaction between crop establishment techniques and integrated nutrient management failed to exert any significant effect on total potassium uptake during both the years of investigation.

4.7 Post harvest soil analysis

Data in respect of post harvest soil analysis that includes soil pH, soil organic carbon (%), soil microbial population and nutrient status as influenced by crop establishment techniques and integrated nutrient management are presented in Table 4.23 and 4.24 and their analyses of variance is presented in Annexure XXIII and XXIV.

4.7.1 Soil pH

Effect of crop establishment techniques

No significant difference in soil pH was observed due to different crop establishment techniques during both the years of investigation.

Effect of integrated nutrient management

The integrated nutrient management practices did not show any significant difference in soil pH during both the years of investigation. Baneerje *et al.* (2018) also reported that the soil pH remain unaffected due to different integrated nutrient management practices in sugarcane.

Interaction effect

Soil pH during both the years of investigation remained unaffected due to interaction effect between crop establishment techniques and integrated nutrient management.

4.7.2 Soil organic carbon (%)

Effect of crop establishment techniques

The soil organic carbon (%) did not differ from each other due to different crop establishment techniques in both the years.

Effect of integrated nutrient management

The soil organic carbon was significantly influenced by different integrated nutrient management practices during both the years. The addition of different sources of nutrients along with inorganic fertilizers recorded significantly higher organic soil carbon than the sole application of 100% RDF (F₁) during both the years of investigation. The application of 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) recorded significantly higher organic carbon (0.85 and 0.84%) which was at par with 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (0.83 and 0.82%), but found to be superior to the application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea+ biofertilizers @ 10 kg ha⁻¹ (F₂) (0.82 and 0.80%) and 100 % RDF+ enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (0.80 and 0.78%) during 1st and 2nd year, respectively. However, F₂, F₃ and F₅ were at par with each other during both the years.

The significant increase in organic carbon under the integrated application of nutrient management (F₄) was due to the addition of more amount of organic matter through addition of animal manure, vermicompost, biofertilizers and green manuring to the crop. Jha *et al.* (2019) also reported a considerable reduction in soil organic matter due to application of 100% RDF as compared to integrated

Table 4.23. Effect of crop establishment techniques and integrated nutrient management on soil properties and microbial population at harvest of sugarcane

Treatments	Soil pH		Organic carbon (%)		Fungal population (10^4 *cfu g ⁻¹ soil)		Bacterial population (10^6 *cfu g ⁻¹ soil)	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Crop establishment techniques (M)								
M ₁ :Conventional method	5.39	5.43	0.80	0.78	5.18	5.12	6.06	6.01
M ₂ : Bud chip seedling at 90 cm x 60 cm	5.41	5.45	0.80	0.79	5.22	5.16	6.11	6.03
M ₃ :Bud chip seedling at 120 cm x 60 cm	5.40	5.44	0.81	0.79	5.20	5.15	6.10	6.05
SEm±	0.06	0.07	0.01	0.01	0.09	0.08	0.09	0.10
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Integrated nutrient management practices (F)								
F ₁ : 100% RDF	5.44	5.46	0.73	0.71	4.71	4.62	4.94	4.85
F ₂ : 100% RDF + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	5.42	5.45	0.82	0.80	5.23	5.19	6.32	6.24
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	5.41	5.44	0.80	0.78	5.21	5.16	6.26	6.22
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	5.37	5.43	0.85	0.84	5.44	5.38	6.51	6.45
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	5.35	5.41	0.83	0.82	5.41	5.36	6.44	6.40
SEm±	0.02	0.03	0.01	0.01	0.07	0.05	0.06	0.07
CD (P=0.05)	NS	NS	0.02	0.02	0.19	0.16	0.18	0.19
Interaction (M x F)								
SEm±	0.03	0.05	0.01	0.01	0.11	0.09	0.11	0.12
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Note: DAP: Days after planting; RDF: Recommended dose of fertilizer; GM: green manuring; VC: vermicompost; EC: Enriched compost; BF: Biofertilizers; SEM±: Standard error of mean; CD: Critical difference, NS: Non significant

application of both organic and inorganic fertilizers. Many researchers reported improvement in soil organic carbon due to application of animal manure, green manure, FYM, biofertilizers *etc.* (Parham *et al.*, 2002; Saviozzi *et al.*, 2002; Sharma *et al.* 2006; Lakshmi *et al.*, 2011 and Kumar and Chand, 2013).

4.7.3 Soil microbial population

4.7.3.1 Fungal population (10^4 *cfu g⁻¹ soil)

Effect of crop establishment techniques

The different crop establishment techniques did not affect the fungal population in soil after harvest of sugarcane during both the years.

Effect of integrated nutrient management

The fungal population determined after harvesting of crop was significantly influenced by different integrated nutrient management practices during both the years. All the integrated nutrient management practices produced significantly higher fungal population as compared to 100% RDF (F₁). The integrated application of 75% RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) recorded significantly higher number of fungal population (5.44 and 5.38 x 10⁴*cfu g⁻¹ soil) which was at par with the integrated application of 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (5.41 and 5.36 x 10⁴*cfu g⁻¹ soil), but superior to the treatments receiving 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) (5.23 and 5.19 x 10⁴*cfu g⁻¹ soil) and 100 % RDF + FYM @ 1 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) (5.21 and 5.16 x 10⁴*cfu g⁻¹ soil) during 1st and 2nd year, respectively. No significant difference was observed between F₂ and F₃ in respect of fungal population in soil during both the years.

Interaction effect

The interaction effect between crop establishment techniques and integrated nutrient management did not show any significant difference in fungal population during both the years of investigation.

4.7.3.2 Bacterial population (10^6 *cfu g⁻¹ soil)

Effect of crop establishment techniques

Bacterial population after harvest of sugarcane remained unaffected due to different crop establishment techniques during both the years.

Effect of integrated nutrient management

The effect of integrated nutrient management on bacterial population was found to be significant during both the years. The integrated application of 75% RDF + FYM @ 1 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) recorded significantly higher bacterial population (6.51 and 6.45 10^6 *cfu g⁻¹ soil) as compared to 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) (6.32 and 6.24 x 10^6 *cfu g⁻¹ soil) and 100 % RDF + green manuring of cowpea + enriched compost @ 1 t ha⁻¹ (F₃) (6.26 and 6.22 x 10^6 *cfu g⁻¹ soil) but found to be at par with 75 % RDF + FYM @ 1 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ @ 1 t ha⁻¹ + green manuring of cowpea (F₅) (6.44 and 6.40 x 10^6 *cfu g⁻¹ soil) during 1st and 2nd year, respectively. The effect of F₂, F₃, and F₅ was at par with each other in regards to the bacterial population during both the years. The least bacterial population was recorded under 100% RDF (F₁) (4.94 x 10^6 *cfu g⁻¹ soil in 1st year and 4.85 x 10^6 *cfu g⁻¹ soil in 2nd year).

The integration of organic sources with 75% RDF improved the soil microbial status as compared to integration with 100% RDF. The reduced application of inorganic N and P fertilizers might have stimulated higher phosphatase and urease activity to release more nutrients for microbial utilization for increasing their multiplication. Kumar *et al.* (2015) also reported higher microbial population with the application of bio-fertilizer along with 75% RDF than NPK alone.

Interaction effect

No significant interaction effect was observed between crop establishments techniques and integrated nutrient management in respect of bacterial population during both the years of investigation.

4.7.4 Soil nutrient status at harvest

Data pertaining to post harvest soil nutrient status such available N, P₂O₅ and K₂O are presented in Table 4.24 and their analyses of variance are presented in Annexure XIV.

4.7.4.1 Available nitrogen (N) content in soil (kg ha^{-1})

Effect of crop establishment techniques

The available N content in soil was not significantly influenced by different crop establishment techniques during both the years.

Effect of integrated nutrient management

Application of different integrated nutrient management practices significantly influenced the available N content in soil during both the years. The integration of chemical fertilizers along with different sources of nutrients significantly increased the soil available nitrogen after harvesting of crop as compared to sole application of inorganic fertilizers. Though the application of 75% RDF + FYM @ 1 t ha^{-1} + vermicompost @ 1 t ha^{-1} + green manuring of cowpea + biofertilizers @ 10 kg ha^{-1} (F_4) recorded significantly higher amount of available N (249.43 and $247.76 \text{ kg ha}^{-1}$) but was at par with 75% RDF + FYM @ 1 t ha^{-1} + enriched compost @ 1 t ha^{-1} @ 1 t ha^{-1} + green manuring of cowpea (F_5) (247.84 and $243.73 \text{ kg ha}^{-1}$), 100% RDF + vermicompost @ 1 t ha^{-1} + green manuring of cowpea + biofertilizers @ 10 kg ha^{-1} (F_2) (246.52 and $242.75 \text{ kg ha}^{-1}$) and 100 % RDF + enriched compost @ 1 t ha^{-1} + green manuring of cowpea (F_3) (245.60 and $241.48 \text{ kg ha}^{-1}$) during 1st and 2nd year, respectively. All of them were found superior to the application of 100% RDF (F_1) ($224.96 \text{ kg ha}^{-1}$ in 1st year and $220.83 \text{ kg ha}^{-1}$ in 2nd year).

Interaction effect

The interaction effect between crop establishment techniques and integrated nutrient management did not show any difference on available N content in soil during both the years of investigation.

4.7.4.2 Available phosphorous (P_2O_5) content in soil (kg ha^{-1})

Effect of crop establishment techniques

The available phosphorous content in soil was not significantly influenced by different crop establishment techniques during both the years.

Effect of integrated nutrient management

The available phosphorous content was significantly influenced by different integrated nutrient management practices during both the years. The treatments comprised of integrated nutrient management significantly increased the soil available

P_2O_5 after harvesting of crop as compared to sole application of inorganic fertilizer 100% RDF (F_1) during both the years. The application of 75% RDF + FYM @ 1 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F_4) recorded the higher amount of available P_2O_5 (21.37 and 21.14 kg ha⁻¹) followed by 75% RDF + FYM @ 1 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F_5) (20.94 and 21.02 kg ha⁻¹), 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F_2) (20.98 and 20.48 kg ha⁻¹) and 100 % RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F_3) (20.75 and 20.33 kg ha⁻¹) during 1st and 2nd year, respectively. All of them were at par with each other, but significantly higher than the application of 100% RDF (F_1) (18.38 kg ha⁻¹ in 1st year and 17.72 kg ha⁻¹ in 2nd year).

Interaction effect

The interaction effect between crop establishment techniques and integrated nutrient management did not show any significant difference in available P_2O_5 content in soil during both the years of investigation.

4.7.4.2 Available potassium (K_2O) content in soil (kg ha⁻¹)

Effect of crop establishment techniques

The different crop establishment techniques did not influence the available potassium content in soil during both the years.

Effect of integrated nutrient management

The available potassium content in soil was significantly influenced by different integrated nutrient management practices during both the years. Significantly higher amount of available K_2O content was recorded under the integrated supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F_2) (198.13 and 196.32 kg ha⁻¹) which was at par with the application of 100 % RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F_3) (195.76 and 192.62 kg ha⁻¹), but significantly superior to the treatments receiving 75% RDF + FYM @ 1t ha⁻¹ + vermicompost @1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F_4) (190.70 and 187.12 kg ha⁻¹) and 75 % RDF + FYM @ 1t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F_5) (186.62 and 184.26 kg ha⁻¹) during 1st and 2nd year, respectively. But, all of them were found superior to the application of 100% RDF (F_1) (174.82 kg ha⁻¹ in 1st year and 173.34 kg ha⁻¹ in 2nd year).

Table 4.24. Effect of crop establishment techniques and integrated nutrient management on nutrient status of soil after harvest

Treatments	Available N (kg ha ⁻¹)		Available P ₂ O ₅ (kg ha ⁻¹)		Available K ₂ O (kg ha ⁻¹)	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Crop establishment techniques (M)						
M ₁ :Conventional method	241.16	238.88	19.51	19.83	187.06	184.54
M ₂ : Bud chip seedling at 90 cm x 60 cm	243.66	239.26	20.57	20.12	189.68	186.28
M ₃ :Bud chip seedling at 120 cm x 60 cm	244.79	240.13	21.38	20.16	190.93	189.38
SEm±	4.35	5.44	0.53	0.59	5.08	4.32
CD(0.05)	NS	NS	NS	NS	NS	NS
Integrated nutrient management practices (F)						
F ₁ : 100% RDF	224.96	220.83	18.38	17.72	174.82	173.34
F ₂ : 100% RDF + VC @ 1t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	246.52	242.75	20.98	20.48	198.13	196.32
F ₃ : 100% RDF + EC @ 1 t ha ⁻¹ + GM	245.60	241.48	20.75	20.33	195.76	192.62
F ₄ : 75% RDF + FYM @ 5 t ha ⁻¹ + VC @ 1 t ha ⁻¹ + GM + BF @ 10 kg ha ⁻¹	249.43	247.76	21.37	21.14	190.70	187.12
F ₅ : 75% RDF + FYM @ 5 t ha ⁻¹ + EC @ 1 t ha ⁻¹ + GM	247.84	243.73	20.94	21.02	186.62	184.26
SEm±	2.06	2.31	0.27	0.32	2.27	2.54
CD(0.05)	6.02	6.74	0.78	0.94	6.63	7.42
Interaction (M x F)						
SEm±	3.57	3.99	0.46	0.56	3.93	4.40
CD(0.05)	NS	NS	NS	NS	NS	NS

Note: DAP: Days after planting; RDF: Recommended dose of fertilizer; GM: green manuring; VC: vermicompost; EC: Enriched compost; BF: Biofertilizers; SEm±: Standard error of mean; CD: Critical difference, NS: Non significant

Interaction effect

The available K_2O content in soil during both the years of investigation was non-significant due to interaction effect between crop establishment techniques and integrated nutrient management.

The increase in available N, P_2O_5 and K_2O in soil might be due to better supply of nutrients under integrated nutrient management systems. Apart from nutrient released from inorganic sources, the addition the organic matter and the activity of microbes like *Azotobacter* and PSB might have helped in release of more nutrients to the soil. Aruna and Mohammad (2005) also stated efficient supply of nutrients to crop owing to slow decomposition of organic materials that helped in sustaining better crop growth and also improved soil properties. The integrated application of FYM, seasoned pressmud and fertilizers had marked influence on the available N in the soil (Venkata *et al.*, 2012). Yadav *et al.* (2018) also reported more available nutrients in soil after harvesting of crop due to integrated application of organic and inorganic sources of nutrients as compared to sole application of inorganic fertilizers. The enhancement in soil fertility under integrated management practices was also reported by Jha *et al.* (2019).

4.7 Economics

Economics of cultivation of autumn sugarcane *viz.*, cost of cultivation, gross return, net return and cost-benefit ratio are presented in Table 4.25 and the details of cost of production per hectare calculated for all the treatments are presented in Annexure III (a), III (b), III(c), III(d) and III(e).

The economics worked out under various treatment combination, the combined effect of the planting of bud chip seedling at 90 cm x 60 cm along with the 75% RDF + FYM @ 1 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (M₂F₅) registered the maximum cost of cultivation (₹ 1,47,068 ha⁻¹ in 2017-18 and ₹ 1,48,299 ha⁻¹ in 2018-19) against the minimum cost recorded under the conventional method with 100% RDF (M₁F₁) (₹ 92,988 ha⁻¹ in 2017-18 and ₹ 94,168 ha⁻¹ in 2018-19). The high cost of cultivation under M₂F₅ was due to application of more amount of organic manures associated with high labour cost involved in nursery as well as in main field. While, the less maintenance cost under the conventional method cost associated with only the application of inorganic fertilizers curtailed the cost of cultivation as compared to other integrated nutrient management practices.

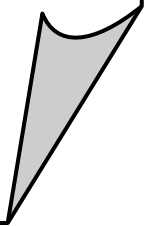
Table 4.25. Economics of crop establishment techniques and integrated nutrient management practices applied to sugarcane

Treatments	Cost of cultivation (₹ ha ⁻¹)		Gross return (₹ ha ⁻¹)		Net return (₹ ha ⁻¹)		B:C ratio	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
M ₁ F ₁	92988	94168	248932	231492	155944	137324	2.68	2.46
M ₁ F ₂	108338	109518	313088	295648	204750	186130	2.89	2.70
M ₁ F ₃	114838	116018	301229	283789	186391	167771	2.62	2.45
M ₁ F ₄	114618	116898	291335	273895	176717	156997	2.54	2.34
M ₁ F ₅	122318	123398	288527	271087	166209	147689	2.36	2.20
M ₂ F ₁	117538	119069	285021	269981	167483	150912	2.42	2.27
M ₂ F ₂	133088	134419	328144	313104	195056	178685	2.47	2.33
M ₂ F ₃	139588	140919	324835	309795	185247	168876	2.33	2.20
M ₂ F ₄	140568	141799	317536	302496	176968	160697	2.26	2.13
M ₂ F ₅	147068	148299	320825	305785	173757	157486	2.18	2.06
M ₃ F ₁	105168	106568	307613	292253	202445	185685	2.92	2.74
M ₃ F ₂	120518	121918	382906	367546	262388	245628	3.18	3.01
M ₃ F ₃	127018	128418	381872	366512	254854	238094	3.01	2.85
M ₃ F ₄	128438	129298	366397	351037	237599	221739	2.85	2.71
M ₃ F ₅	134498	135798	357629	342269	223131	206471	2.66	2.52

Whereas, the gross return of ₹ 3,82,906 ha⁻¹ during 2017-18 and ₹ 3,67,546 ha⁻¹ during 2018-19 was obtained due to planting of bud chip seedling at 120 cm x 60 cm along with the supply of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (M₃F₂) and the minimum gross return was obtained due to application of 100% RDF under conventional method (M₁F₁) (₹ 2,48,932 ha⁻¹ during 2017-18 and ₹ 2,31,492 ha⁻¹ during 2018-19). The planting of bud chip seedling at 120 cm x 60 cm along the application 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (M₃F₂) also recorded the highest net return of ₹ 2,62,388 ha⁻¹ during 2017-18 and ₹ 2,45,628 ha⁻¹ during 2018-19. The maximum B-C ratio of 3.18 during 1st and 3.01 in 2nd year were also obtained under the treatment M₃F₂.

Significantly higher cane yield obtained under planting of bud chip seedling at 120 cm x 60 cm along the application 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (M₃F₂) resulted the higher gross return. While, the reduced cost of cultivation accompanied with higher gross return resulted in higher net return as well as B-C ratio. On the other hand, the high cost of cultivation associated with other treatment combination could not bring out good economic return. Sugeerthi *et al.* (2018) also reported higher gross return, net return and B-C ratio under the planting of bud chip seedling 75% RD of NPK + Azophos + *in situ* incorporation of sun hemp + foliar spraying of sugarcane booster.

Summary and Conclusion... 



CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted to study the “Performance of bud chip seedlings under integrated nutrient management in autumn planted sugarcane (*Saccharum officinarum* L.)”. The investigation was carried out for two consecutive years of 2017-18 and 2018-19 at Sugarcane Research Station, Assam Agricultural University, Buralikson, Assam. The experiment consisted of three crop establishment techniques in main plot *viz.*, M₁: Conventional method of planting M₂: Planting of bud chip seedling at 90 cm x 60 cm, M₃: Planting of bud chip seedling at 120 cm x 60 cm and five integrated nutrient management practices under sub plot *viz.*, F₁:100 % RDF, F₂: 100 % RDF + vermicompost @ 1 t ha⁻¹+ green manuring (cowpea incorporation) + biofertilizers @ 10 kg ha⁻¹ F₃: 100 % RDF + enriched compost @ 1 t ha⁻¹ + green manuring (cowpea incorporation), F₄:75 % RDF + FYM @ 5 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring (cowpea incorporation) + biofertilizers @ 10 kg ha⁻¹, F₅: 75% RDF + FYM @ 5 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring (cowpea incorporation). The soils of the experimental site in both the years were clay loam in texture, acidic in nature (pH 5.46 and 5.48), medium in organic carbon (0.71 and 0.68%) and available K₂O (194.33 and 187.66 kg ha⁻¹), low in available N (231.42 and 226.77 kg ha⁻¹) and available P₂O₅ (19.28 and 18.64 kg ha⁻¹). The experiment was laid out in split plot design with three replications.

From the present investigation, an attempt has been made to summarize the salient findings in terms of crop growth parameters, yield attributing characters and yield, juice quality, plant analysis, soil health and nutrient status as well as the economics of sugarcane under various treatments and tried to draw a conclusion based on all the above parameters.

A. Effect of crop establishment techniques on the performance of autumn planted sugarcane

1. The plant growth parameters like total number of shoots ha⁻¹, number of shoots plant⁻¹, plant height recorded at various crop growth stages were found to be significantly higher due to planting bud chip seedling at 120 cm x 60 cm

spacing as compared to the planting of bud chip seedling at 90 cm x 60 cm as well as conventional method during the grand growth stages of crop during both the years of investigation. But, in early stage of crop growth, no significant difference was observed between planting of bud chip seedling at 120 cm x 60 cm and 90 cm x 60 cm spacing. But, in case of growth parameters like, leaf area shoot⁻¹ and physiologically active leaves shoot⁻¹, planting of bud chip seedling at 120 cm x 60 cm spacing was found to be significantly higher over conventional method, but at par with planting of bud chip seedling at 90 cm x 60 cm spacing during both the years of study.

2. The different crop establishment techniques also significantly influenced the plant growth indices like leaf area index (LAI), leaf area duration (LAD), crop growth rate (CGR) recorded at different crop growth stages during both the years. The planting of bud chip seedling at 120 cm x 60 cm spacing recorded significantly higher values of LAD and CGR during 210-270 DAP as compared to other crop establishment techniques, but at par with planting of bud chip seedling at 90 cm x 60 cm in respect of data recorded during 150-210 DAP. Similarly, significantly higher LAI was recorded at different crop stages due to planting of bud chip seedling at 120 cm x 60 cm spacing. However, no significant difference was observed in case of relative growth rate (RGR) during both the years.
3. The N- related parameters such as crop canopy temperature, chlorophyll content as well as green seeker NDVI did not show any significant difference due to different crop establishment techniques.
4. The total dry matter production as well dry matter produced by stem were significantly increased due to planting of bud chip seedling at 120 cm x 60 cm as compared to planting of bud chip seedling at 90 cm x 60 cm as well as conventional method. But, no such remarkable effect was observed in case of dry matter produced by leaves during both the years.
5. The below ground biometric observation like root length and root dry weight were significantly influenced by different crop establishment techniques and significantly higher values were recorded under the planting of bud chip seedling at 120 cm x 60 cm spacing as compared to other crop establishment techniques during both the years.

6. The yield attributing characters like length of millable cane, number of millable cane, number of internodes millable cane⁻¹, length of internode (bottom) recorded under the planting of bud chip seedling at 120 cm x 60 cm spacing were found to be significantly superior over the other crop establishment techniques. The planting of bud chip seedling at 120 cm x 60 cm spacing also recorded significantly higher values in respect of length of internode recorded at middle and top portion of millable cane, average cane weight as compared to conventional method, but found at par with the planting of bud chip seedling at 90 cm x 60 cm spacing during both the years. However, no significant difference was observed between planting of bud chip seedling at 90 cm x 60 cm and conventional method in case of all the yield attributing characters. Besides this, diameter of millable cane remained unaffected due to different crop establishment techniques during both the years.
7. The different crop establishment techniques significantly influenced the cane, green top and trash yield during both the years. The highest cane and trash yield of both individual years's as well as in pooled analysis were achieved under the planting of bud chip seedling at 120 cm x 60 cm. But, the green top yield recorded under the planting of bud chip seedling at 120 cm x 60 cm was found to be significantly higher than conventional method, but was at par with planting of bud chip seedling at 90 cm x 60 cm during both the years. The planting of bud chip seedling at 120 cm x 60 cm recorded 19.70, 17.89 and 20.15% increased in cane yield over conventional method for 2017-18, 2018-19 and in pooled analysis, respectively.
8. Significantly higher biological yield was obtained due to planting of bud chip seedling at 120 cm x 60 cm as compared to other crop establishment techniques, but no significant difference was observed in case of harvest index recorded during both the years.
9. The different crop establishment techniques did not influence the qualitative studies of sugarcane such as field brix, juice recovery, sucrose, CCS, purity and CCS (%) during both the years. Nevertheless, planting of sugarcane bud chip seedling slightly improved the juice quality as compared to conventional method of planting. But, planting of sugarcane bud chip seedling at 120 cm x

60 cm revealed significantly higher sugar as well as jaggery yield as compared to other crop establishment techniques during both the years.

10. The per cent N, P and K content in cane stalk, green top and trash were not significantly influenced by different crop establishment techniques during both the years. However, the highest uptake of nutrients by different plant parts as well as total nutrients uptake by plant was observed due to planting of sugarcane bud chip seedling at 120 cm x 60 cm during both the years.
11. The soil properties like pH and organic carbon %, soil microbial population and status of available N, P₂O₅ and K₂O in the soil after harvest of sugarcane remained unaffected due to different crop establishment techniques during both the years of study.

B. Effect of integrated nutrient management on the performance of autumn planted sugarcane

1. The plant growth parameters such as total number of shoots ha⁻¹, number of shoots plant⁻¹, number of physiologically active leaves shoot⁻¹, leaf area stalk⁻¹ and plant height were significantly influenced by different integrated nutrient management practices over 100% RDF (F₁). The integrated application of 100% RDF+ vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded the highest values in case of all the growth parameters recorded at different growth stages during both the years. However, in certain parameters like number of physiologically active leaves shoot⁻¹, all the treatments receiving integrated nutrient management were found to be at par with each other throughout the crop growing period during both the years. But, in case of plant height, the application of 100% RDF+ vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly which was found to be at par with 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) in early stage of crop growth, but, at later stages of crop growth, all the treatments receiving integrated nutrient management was found to be at par with each other.
2. The growth indices *viz.*, leaf area index (LAI), leaf area duration (LAD) and crop growth rate (CGR), relative growth rate (RGR) were significantly influenced by integrated nutrient management practices. All the integrated nutrient management practices significantly increased the crop growth indices as

compared to 100% RDF (F_1) during both the years. In case of all the parameters, the application 100% RDF+ vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F_2) recorded significantly higher values throughout crop growing period, but, found at par with all the treatments comprised of integrated nutrients management in case of LAI recorded at 300 DAP, CGR and RGR recorded at 270-330 DAP during both the years.

3. The N- related parameters such as total chlorophyll content recorded at 240 and 330 DAP and crop canopy temperature, green seeker NDVI recorded at 330 DAP were significantly influenced by integrated nutrient management practices. All the treatments receiving integrated nutrient management were found to be at par with each other but superior to 100% RDF (F_1). However, comparatively higher values were obtained due to the application of 100% RDF+ vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F_2) during both the years of investigation.
4. The integrated application 100% RDF+ vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F_2) significantly increased the root length as well root dry weight recorded at 120, 150 and 180 DAP, as compared to sole inorganic fertilizers (100% RDF), but found to be at par with all the treatments comprised of integrated nutrient management in respect of root length recorded at 120 and 150 DAP and root dry weight at 180 DAP during both the years of study.
5. The integrated nutrient management significantly influenced the dry weight of above ground biomass that includes the dry matter production by leaves and stem as well as total dry matter production shoot⁻¹ recorded at 210 and 270 DAP during both the years. In both stages *viz.*, at 210 and 270 DAP, integrated application of 100% RDF+ vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F_2) recorded significantly higher dry matter production by stem as well as total dry matter production which were at par with 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F_3) during both the years. Similarly, significantly higher dry matter production by leaves were also obtained under the integrated supply of 100% RDF+ vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg

ha⁻¹ (F₂) which was found to be at par with all other treatments except 100% RDF (F₁) at 210 DAP in both the years of experimentation.

6. Application of 100% RDF+ vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded the maximum values in all the yield attributing characters *viz.*, length of millable cane, number of millable cane, average cane weight, length of internodes (bottom, middle and top portion of millable cane), number of internodes millable cane⁻¹ which was found to be at par with all the other treatments except 100% RDF (F₁). But, diameter of the cane remained unaffected due to various integrated nutrients management practices during both the years of study.
7. The highest cane yield of both individual years as well as pooled data of sugarcane were obtained due to application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) which was found to be at par with all the other treatments excluding 100% RDF during both the years. The same treatment also registered the higher green top as well as trash yield for both 2017-18, 2018-19 and pooled analysis. However, in case of green top yield all the treatments receiving integrated supply of nutrients were at par with each other during 1st and 2nd years of investigation. The combined application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) registered 12.67, 12.32 and 12.49% increase in cane yield for 2017-18, 2018-19 and in pooled analysis over the 100% RDF(F₁). The integrated application of 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher biological yield which was found to be at par with all the treatments excluding 100% RDF during both the years. But, no significant difference in harvest index% was recorded during both the years.
8. The various integrated nutrient management practices did not exhibited any significant difference on qualitative parameters such as field brix recorded at bottom, middle and top portion of standing cane recorded at 360 and 420 DAP, sucrose and purity (%) of cane juice at the time of harvesting during both the years. But, all the integrated nutrient management practices significantly increased the other qualitative parameters such as juice recovery or extraction (%), CCS of cane juice (%) and CCS yield (t ha⁻¹) at the time of harvesting as

compared to 100% RDF during both the years. In case of juice recovery and CCS%, the maximum values were obtained with the application of 100% RDF + green manuring of cowpea + vermicompost @ 1 t ha + biofertilizers @ 10 kg ha⁻¹ (F₂), which was at par with all the INM treatments except 100% RDF. The same treatment (F₂) also recorded significantly higher CCS yield, but found at par with the treatment receiving 100% RDF+ enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) during both the years.

9. All the integrated nutrient management practices significantly increased the jaggery recovery (%) and Jaggery yield (t ha⁻¹) as compared to 100% RDF during both the years. The application of 100% RDF+ vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher jaggery yield which was at par with 100 % RDF + green manuring of cowpea + enriched compost @ 1 t ha⁻¹ (F₃). Similarly, significantly higher amount of jaggery recovery (%) was also obtained under the integrated supply of 100% RDF+ vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂), but, found to be at par with all other treatments receiving integrated nutrient management in both the years.
10. The nitrogen content in different plant parts (green top, cane stalk and trash) as well as potassium content in cane stalk was significantly influenced by different integrated nutrient management practices during both the years. Other than these, the integrated nutrient management did not exhibit any significant difference in P and K content of different plant parts during both the years. The application of 100% RDF+ vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) significantly increased the nitrogen content in green top, cane stalk and trash of a plant as compared to 100% RDF, but found to be at par with all other treatments in case of nitrogen content in cane stalk and trash during both the years. Similarly, the higher amount of potassium content in cane stalk was also registered under the treatment receiving 100% RDF + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) in both the years.
11. The nutrients nitrogen, phosphorus and potassium uptake by different plant parts such as green top, cane stalk and trash and subsequently the total nutrient uptake by plant significantly increased under different integrated nutrient management

practices as compared to the inorganic fertilizers alone. The integrated application of 100% RDF+ vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) recorded significantly higher nitrogen, phosphorous and potassium uptake by green top, cane stalk and trash as well as total uptake of nutrients in both the years.

12. The integrated nutrient management practices significantly improved the post harvest soil organic carbon, nutrient status as well as microbial population as compared to inorganic fertilizers alone. The integrated supply of 75% RDF + FYM @ 1 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) recorded higher organic carbon, fungal and bacterial population which was at par with the application of 75 % RDF + FYM @ 1 t ha⁻¹ + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₅) in both the years. Similarly, significantly higher amount of available N and P₂O₅ was also registered under the treatment receiving 75% RDF + FYM @ 1 t ha⁻¹ + vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₄) which was found to be at par with all the treatments comprised of integrated nutrient management in both the years. While, significantly higher amount of available K₂O were registered under the integrated application of 100% RDF+ vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (F₂) which was found to be at par with 100% RDF + enriched compost @ 1 t ha⁻¹ + green manuring of cowpea (F₃) in both the years. But, the integrated nutrient management practices did not exert any significant difference on soil pH during both the years of investigation.

C. Interaction effect of crop establishment techniques and integrated nutrient management on the performance of autumn planted sugarcane

1. The interaction effect between the crop establishment techniques and integrated nutrient management was found to be significant on total numbers of shoots recorded at 180 and 210 DAP, number of shoots plant⁻¹ at 180 and 210 DAP, leaf area duration (LAD) recorded during 150-210 and 210-270 DAP in both the years. Irrespective of crop establishment techniques, the applications of integrated nutrient management significantly increased all the values as compared to inorganic fertilizers alone. The treatment combination of planting of bud chip seedling at 120 cm x 60 cm and 100% RDF+ vermicompost @ 1 t

ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (M₃F₂) recorded significantly higher values of all these parameters as compared to other treatments in both the years.

D. Effect of various treatment combinations on economics of autumn planted sugarcane

1. In autumn planted sugarcane, planting of bud chip seedling at 120 cm x 60 cm along the application 100% RDF+ vermicompost @ 1 t ha⁻¹ + green manuring of cowpea + biofertilizers @ 10 kg ha⁻¹ (M₃F₂) registered the maximum gross return (₹ 3,82,906 ha⁻¹ and ₹ 3,67,546 ha⁻¹), net return (₹ 2,62,388 ha⁻¹ and ₹ 2,45,628 ha⁻¹) and B-C ratio (3.18 and 3.01) for the 2017-18 and 2018-19, respectively.

CONCLUSION

Based on growth, yield, economics indices, quality parameters as well as soil health of present experiment, it may be concluded that planting of sugarcane bud chip seedling at 120 cm x 60 cm spacing along with the application of 100 % RDF, vermicompost @ 1 t ha⁻¹ and biofertilizers @ 10 kg ha⁻¹ including the *in situ* growing and incorporation of cowpea as green manuring crop may be recommended for autumn planted sugarcane cultivation in Assam.

Plates... 

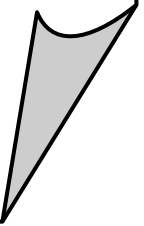




Plate 1. Preparation for layout of the experiment



Plate 2. Extraction of bud chip from cane



Plate 3. Shade drying of bud chip after treating with fungicidal solution



Plate 4. Raising of bud chip seedling in nursery



Plate 5. Bud chip seedling ready for transplanting



Plate 6. Application of organic manure in pit before transplanting of the bud chip seedling



Plate 7. Transplanting of bud chip seedling in main field



Plate 8. Transplanting of bud chip seedling in main field (close view)



Plate 9. Cowpea as green manuring crop in between the rows of sugarcane



Plate 10. Tillingering stage as affected by planting of bud chip seedling at 120 cm x 60 cm along with 100 % RDF + VC @ 1 t ha⁻¹ + GM + BF @ 10 kg ha⁻¹ (M₃F₂)



Plate 11. Comparison of height under different crop establishment techniques during 2017-18



Plate 12. General view of experiment during grand growth stage (2017-18)



Plate 13: Overall view of the experimental plot during 2017-18



Plate 14. Experimental field visit by Major advisor, Ex HoD and then CS and present HoD



Plate 15. Visual difference of plant height at maturity during 2018-19



Plate 16. Early grand growth stage as affected by conventional method and 100% RDF (M_1F_1)



Plate 17. Grand growth stage as affected by conventional method and 75 % RDF + FYM @ 5 t ha^{-1} + VC @ 1 t ha^{-1} + GM + BF @ 10 kg ha^{-1} (M_1F_4)



Plate 18. Grand growth stage as affected by planting of bud chip seedling at $90 \text{ cm} \times 60 \text{ cm}$ along with 100 % RDF (M_2F_1)



Plate 19. Grand growth stage as affected by planting of bud chip seedling at 120 cm x 60 cm along with 100% RDF + VC @ 1t ha⁻¹ + GM + BF@ 10 kg ha⁻¹ (M₃F₂)



Plate 20. Grand growth stage as affected by planting of bud chip seedling at 120 cm x 60 cm along with 100 % RDF + EC @ 1 t ha⁻¹ + GM (M₃F₃)



Plate 21. Grand growth stage as affected by planting of bud chip seedling at 120 cm x 60 cm along with 75 % RDF + FYM @ 5 t ha⁻¹ + VC @ 1 t ha⁻¹ + GM + BF @ 10 kg ha⁻¹ (M₃F₄)



Conventional method



Bud chip seedling

Plate 22. Comparison of root growth between conventional method (M₁) and bud chip seedling planting at 120 cm x 60 cm (M₃)



Plate 23. Recording of number of millable cane at the time of harvesting



Plate 24. Recording of crop canopy temperature with IR thermometer



Plate 25. Measurement of length of internodes of millable cane at the time of harvesting



Plate 26. Measurement of diameter of millable cane at harvest



Plate 27. Cane yield recorded under planting of bud chip seedling at 120 cm x 60 cm along with 100 % RDF + VC @ 1 t ha⁻¹ + GM+ BF@1o kg ha⁻¹ (M₃F₂)



Plate 28. Cane yield recorded under planting of bud chip seedling at 120 cm x 60 cm along with 100 % RDF + EC @ 1 t ha⁻¹ + GM (M₃F₃)




Plate 29. Early maturity stage as affected by planting of bud chip seedling at 120 cm x 60 cm along with 100 % RDF + VC @ 1 t ha⁻¹ + GM+ BF@1o kg ha⁻¹ (M₃F₂)

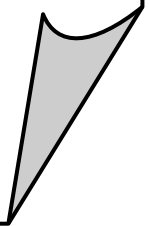


Plate 29. Estimation of chlorophyll content



Plate 30. Estimation of phosphorus content in laboratory

Bibliography... 



BIBLIOGRAPHY

- Abid, M.; Batool, T.; Siddique, G.; Ali, S.; Binyamin, R.; Shahid, M.J.; Rizwan, M.; Alsahli, A.A. and Alyemeni, M.N. (2020). Integrated Nutrient Management Enhances Soil Quality and Crop Productivity in Maize-Based Cropping System. *Sustainability*, **12**: 10214.
- Ahmad, I. (2002). Bio-economic efficiency of spring planted sugarcane as influenced by spatial arrangement and nutrient management. Ph.D. Thesis, Dept. Agron. Uni, Agric., Faisalabad, Pakistan, pp. 155-158.
- Ahmed, Z.A.; Ahmed, A.M. and Osman, H.S.M. (2011). Optimum inter row spacing and number of ploughing for two promising varieties. *Egypt. J. Agric. Res.*, **89**(1): 301-317.
- Ajay, P.; Ramesh, K.; Reddy, S.; Ramana, S. and Maji, B. (2005). Effect of nitrogen and farm yard manure of physiological parameters in ashwagandha under vertisol soil type. *Indian J. Plant Physiol.*, **10**(4): 389-393.
- Anonymous (2020). Estimation of sugar production for 2019-20. Indian sugar Mill Association.
- Aron, D. (1949). Copper enzymes isolated chloroplasts, polyphenoloxidase in *Beta vulgaris*. *Plant Physiol.*, **24**: 1-15.
- Aruna, E. and Mohammad, S. (2005). Influence of conjunctive use of organic and inorganic source of nutrients in rice on crop growth, yield components, yield and soil fertility in rice-sunflower sequence. *Indian J. Agron.*, **50**: 265-268.
- Banerjee, K.; Puste A.M.; Gunri, S.K.; Jana and Barman, K. (2018). Effect of integrated nutrient management on growth, yield, quality and soil health of spring planted sugarcane (*Saccharum officinarum*) in West Bengal. *Indian J. Agron.*, **63**(4): 41-47.
- Bangar, K.S. and Sharma, S.R. (1997). Role of organic manuring in improving sugarcane and sugar productivity. *Indian J. Sugarcane Technol.*, **12**(1): 59-66.
- Banger, K.S.; Maini, A. and Sharma, S.R. (1994). Effect of fertilizer nitrogen and press mud cake on growth, yield and quality of sugarcane. *Crop Res.*, **8**: 23-27.
- Banwasi, R. and Bajpai, R.K. (2001). Effect of intergrated nutrient management on root growth of wheat in a rice-wheat cropping system. *Agric. Sci. Digest*, **21**(1): 1-4.

- Bashir, S.; Saeed, M.; Ghaffar, A.; Ali, Z. and Khan, R.M.Z. (2000). Analysis of economic aspects of raising autumn sugarcane at different planting patterns and seeding densities. *Int. J. Agri. Biol.*, **2**: 322-325.
- Basai, D.; Menossi, M. and Mattiello, L. (2018). Nitrogen supply influences photosynthesis establishment along the sugarcane leaf. *Scientific Reports*, **8**: 23-27.
- Biksham, G. (2011). A Methodology to Improve Cane Productivity. *In: Sustainable Sugarcane Initiative Draft (SSI)*. Sugarcane Breeding Institute and Natural Resources Management Centre. pp. 5-6.
- Bokhtiar, H.; Rehman, R.C. and Rahman, A.B.M.M.. (2005). Efficacies of some organic fertilizers on sustainable sugarcane production in old Himalayan piedmont plain soil of Bangladesh. *Pakistan Sug. J.*, **20**(1): 2-5.
- Bokhtiar, S.M. and Sakurai, K. (2005). Effect of application of inorganic and organic fertilizers on growth, yield and quality of sugarcane. *Sugar Tech.*, **7**(1): 33-37.
- Bokhtiar, S.M. and Sakurai, K. (2007). Effect of integrated nutrient management on plant crop and successive first and second ratoon crop of sugarcane in Bangladesh. *J. Plant Nutr.*, **30**(1): 135-147.
- Bokhtiar, S.M.; Alam, M.J.; Mahmood, K. and Rahman, M.H. (2002). Integrated nutrient management on productivity and economics of sugarcane under three Agro-ecological zones of Bangladesh. *Pakistan J. Biosci.*, **5**(4): 390-393.
- Bokhtiar, S.M.; Roksana, S. and Moslehuddin, A.Z.M. (2015). Soil fertility and productivity of sugarcane influenced by enriched pressmud compost with chemical fertilizers. *SAARC J. Agri.*, **13**(2): 183-197.
- Chakrawal, D. and Kumar, N. (2013). Effect of planting geometry and variety on growth attributes of sugarcane in Indian sub-tropics. *Indian J. Sugarcane Technol.*, **28**(01): 33-36.
- Chandrakar, K.C.; Prabha, N.; Verma, O.N. and Pandey, K.K. (2019). Standardization of planting geometry of sugarcane with suitable intercropping under drip irrigation in Chhattisgarh Plains. *Int. J. Curr. Microbiol. App. Sci.*, **8**(7): 2878-2884.
- Chatta, M.U.; Ali, A. and Bilal, M. (2007). Influence of planting techniques on growth and yield of spring planted sugarcane. *Pakistan J. Agric. Sci.*, **44**(3): 452-457.

- Chattha, A.A.; Afzal, M. and Chattha, M.U. (2004). Sustainable cultivation of sugarcane for revival of sugar industry in Pakistan. *Proc. 39th Ann. Conv. Pak. Soc. Sugar Tech.*, pp. 36-49.
- Chattha, M.U. (2007). Studies on growth, yield and quality of sugarcane (*Saccharum officinarum* L.) under different planting techniques, irrigation, method, water levels and mulch types. Ph.D dissertation, Faculty of Agriculture, University of Agriculture, Faisalabad, Pakistan, p. 172.
- Chaudhari, P.M.; Ombase, K.C.; Thorave, D.S.; Ghodke, S.K. and Pawar, S.M. (2014). Evaluation of planting geometry and different varieties on growth and yield of spring planted sugarcane. *Int. J. Curr. Res.*, **6**(12): 10394-10396.
- Cheema, I.A.; Ayub, M. and Jabbar, A. (2002). Bio economic efficiency of spring planted sugarcane as influenced by spatial arrangement and nutrient management. *Pakistan Sug. J.*, **17**: 62-68.
- Cheema, I.A.; Ayub, M. and Jabbar, A. (2002). Morphological response of spring planted sugarcane to spaced arrangement and nutrient management. *Pakistan Sug. J.*, **17**(6): 62-68.
- Cheero-Nayamath, F.C.; Robertson, M.J.; Wegener, P. and Nayamath, A.R.H. (2000). Using a simulation model to assess potential and attainable sugar yield in Mauritius. *Field Crops Res.*, **66**: 2-14.
- Chiluwal, A.; Singh, H.P.; Sainju, U.; Khanal, B. and Wayne, F. and Singh, B.P. (2018). Spacing Effect on Energy Cane Growth, Physiology, and Biomass Yield. *Crop Sci.*, **57**: 1371-1384.
- Clowes, M.S.J. and Breakwell, W.L. (1998). Zimbabwe sugarcane production manual. Zim. Sug. Assoc. Expt. Stat., Chiredzi, Zimbabwe.
- Dang, Y.P.; Verma, K.S. and Pannu, B.S. (1995). Need for potassium fertilization in sugarcane. *Indian Sugar*, **XLV**: 229-235.
- Datta, S.C. (2000). Plant Physiology, Wiley Eastem Ltd. New Age Intl. Ltd, New Delhi, India, 1994.
- Donald, C.M. and Hamblin, J. (1976). The biological yield and harvest index of cereals as agronomic and plant breeding criteria. *Adv. Agron*, **28**: 361-405.
- Durai, R. and Devaraj, G. (2003). Organic farming in sugarcane. *Cooperative Sugar*, **34**(6): 491-492.
- Dutta, S.; Pal, R.; Chakeraborty, A. and Chakrabarti, K. (2003). Influence of integrated plant nutrient supply system on soil quality restoration in a red and laterite soil. *Arch. Agron. Soil Sci.*, **49**: 631-637.

- Ehsanullah, K.J.; Jamil, M. and Ghafar, A. (2011). Optimizing the row spacing and seedling density to improve yield and quality of sugarcane. *Crop Evt.*, **2**(1): 1-5.
- Felipe, S.; Sandro, L.P.M.; Elvis, F.E.; Elder, E.; Jaqueline, S. and Braulio, O.C. (2018). Plant growth, radiation use efficiency and yield of sugarcane cultivated in agroforestry systems: An alternative for threatened ecosystems. *An Acad. Bras. Cienc.*, **90**(4): 3265-3283.
- Gana, A.K. and Busari, L.D. (2006). Contribution of green and farm yard manure in the nitrogen nutrition of sugarcane. *Sugar Tech.*, **8**(2&3): 175-179.
- Gangwar, K.S. and Sharma, S.K. (1998). Integrated nutrient management in summer planted sugarcane on cultivator's field. *Indian J. Agron.*, **42**(1): 181-183.
- Gangwar, K.S.; Sharma, S.K. and Tomar, O.K. (2003). Integrated nutrient management in late-planted sugarcane – wheat system in Western Uttar Pradesh. *Indian J. Agron.*, **48**(1): 20-22.
- Garside, A.L.; Bell, M.J.; Berthelsen, J.E. and Halpin, N.V. (2002). Effects of fumigation, density and row spacing on the growth and yield of sugarcane in two diverse environments. *Proc. Aust. Soc. Sugarcane Technol.*, **24**: 135-144.
- Ghaffar, A.; Ehsanullah, N.; Akber, S.H.; Khan, K.; Jabran, R.Q.; Hashmi, A.I. and Ali, M.A. (2012). Effect of trench spacing and micronutrients on growth and yield of sugarcane. *Aus. J. Crop Sci.*, **6**(1): 1-9.
- Gill, M.B (1995). Physio-agronomic studies on flat versus pit plantation of autumn and spring Sugarcane (*Saccharum officinarum* L). Ph.D dissertation, Deptt. Agron. Univ.Agric. Faisalabad, Pakistan.
- Gopalasundaram, P.; Bhaskaran, A. and Rakkiyappan, P. (2011). Integrated nutrient management in sugarcane. *Sugar Tech.*, **14**(1): 3-20.
- Goud, V.V. (2011). Sustainable Sugarcane Initiative, SSI - A Methodology for improving yields, First National Seminar on, SSI, pp. 9-12.
- Hunsigi, G. (2001). Sugarcane in Agriculture and Industry. Prism Books Pvt. Ltd., Bengalooru, Karnataka.
- Hunsingi, G. (1993). *Production of sugarcane, theory and practice. Advanced Series in Agricultural Sciences.* India.
- Hunt, R. (1978). Plant Growth Analysis. The Inst. of Bio. Studies in Bio. Edward Arnold (Pub.) Ltd. **96**: 8-38.

- Iqbal, M.T.; Eusufzal, S.U.K. and Rukshana, F. (2002). Performance of sugarcane bud chip settlings. *Indian J. Sugarcane Technol.*, **17**(1,2): 88.
- Irvine, J.E. and Benda, G.T. (1980). Effect of spacing on the plant. *ISST.*, **1**: 350-356.
- Islam, M.S.; Miah, M.A.S.; Begum, M.K.; Alam, M.R. and Arefin, M.S. (2008). Growth, yield and juice quality of some selected sugarcane clones under, water-logging stress condition. *World J. Agril. Sci.*, **7**(4): 504-509.
- Jackson, M.L. 1973. Soil Chemical Analysis. Publisher: Prentica Hall of India Pvt. Ltd., New Delhi.
- Jamuna, P.; Ramlinga Swamy, K. and Naidu, N.V. (2002). Efficacy of biofertilizers in integration with composts and chemical fertilizers in sugarcane. *Biofertilizers Newslett.* **202**: 23-25.
- Jeyaraman, S. and Alagudural, S. (2003). Nitrogen and Phosphorus management with green manure as intercrop and *Phosphobacteria* incorporation in sugarcane. *Indian Sug.*, **1**: 839-842.
- Jha, C.K.; Sinha, S.K.; Thakur, S.K. and Kumar, V. (2019). Soil properties, productivity and juice quality of sugarcane through integration of organic and inorganic nutrient sources in calcareous soil. *Int. J. Chem. Stud.* **SP6**: 297-302.
- Kanjana, D. and Pitchai, J.G. (2009). Effect of organic, inorganic and biofertilizer on yield and yield attributing characteristics of sugarcane Co 86032. *Indian Sugar.*, **59**: 57-60.
- Kapoor, K.K.; Mishra, M.M. and Kudrejaga, K. (1989). Phosphate solubilization by soil micro organisms. *Indian J. Microbiol.*, **29**(2): 119-127.
- Kapur, R.; Duttamajumdar, S.K. and Krishna Rao, K. (2011). A breeder's perspective on the tiller dynamics in sugarcane. *Curr. Sci.*, **100**: 183-189.
- Keshavaiah, K.V.; Palled, Y.B.; Shankaraiah, C.; Channal, H.T.; Nandihalli, B.S. and Jagadeesha, K.S. (2012). Effect of nutrient management practices on nutrient dynamics and performance of sugarcane. *Karnataka J. Agric. Sci.*, **25**(2): 187-192.
- Khalid, S.; Munsif, F.; Ali, A.; Ismail, M.; Haq, N. and Shahid, M. (2015). Evaluation of chip bud settling of sugarcane for enhancing yield to various row spacing. *Int. J. Agril. Envnt. Res.*, **1**(2): 8-13.
- Khaliq, T.; Ahmad, A.; Hussain, A. and Ali, M.A. (2009). Maize hybrids response to nitrogen rates at multiple locations in semiarid environment. *Pakistan J. Bot.*, **41**: 207-224.

- Khan, E.A.; Sagoo, A.G. and Hassan, G. (2011). Physiological response of autumn planted sugarcane to soil moisture depletion and planting geometry on different soils under arid conditions. *Pakistan J. Bot.*, **43**(4): 1965-1969.
- Khatkar, P. and Kuhad, M.S. (2000). Stage sensitivity of wheat cultivars to short terms salinity stress. *Indian J. Pl. Physiol.*, **5**(1): 26-31.
- Krishnamoorthy, R.V. and Vajrabhiah, S.N. (1986). Biological activity of earthworm casts: an assessment of plant growth promoter levels in casts. *Proc. Indian Acad. Sci.*, **95**: 341-351.
- Kumar, D. and Singh, T. (1999). Sustainable sugarcane cultivation with biofertilizers. *Biofert News Lett.*, **7**(1): 12-18.
- Kumar, J.; Kumar, V. and Kavita (2019). Effect of application various combination of fertilizers and manure on sugarcane production and juice quality. *Agric. Sci. Digest.*, **39**(1): 26-30.
- Kumar, M.V. and Suresh, K. (2011). Studies on Physiological Aspects of Growth, Quality and Yield of Bud Chip Technology in Sugarcane. First National Seminar on Sustainable Sugarcane Initiative, SSI, organized by TNAU, Coimbatore, Tamil Nadu, pp. 44-46.
- Kumar, N. (2020). Enhancing sugarcane plant-ratoon productivity through bud chip transplanting geometry. *Sugar Tech.*, <https://doi.org/10.1007/s12355-019-00772-3>.
- Kumar, R.; Uppal, S.K. and Walia, S.S. (2016). Impact of integrated nutrient management strategies on productivity of plant and ratoon crops of sugarcane. *Indian J. Ecol.*, **43**(Special Issue-1): 415-419.
- Kumar, S.H.S.S and Gaddanakeri, S.A. (2015). Site specific nutrient management for target yield and recovery in sugarcane. *Karnataka J. Agric. Sci.*, **28**(1): 16-19.
- Kumar, S.U.; Baskar, K.; Saliha, B. and Jemila, C. (2017). Impact of Integrated Nutrient Management on Soil Fertility and Nutrient Uptake of Ratoon Sugarcane. *Chem. Sci. Rev. Lett.*, **6**(21): 567-573.
- Kumar, V. and Chand, M. (2013). Effect of Integrated Nutrients Management on Cane Yield, Juice Quality and Soil Fertility Under Sugarcane Based Cropping System. *Sugar Tech.*, **15**(2): 214.
- Kumar, V. and Verma, K.S. (2002). Influence of use of organic manure in combination with inorganic fertilizers on sugarcane and soil fertility. *Indian Sugar.*, **52**(3): 177-181.

- Kumar, V.; Verma, K.S. and Talwar, G. (1999). Effect of integrated fertilizer use on cane yield and juice quality of sugarcane. *Co-op. Sug.*, **30**(7): 669-674.
- Kumar, V.; Yadav, K.S. and Chand, M. (2015). Effect of integrated use of various bio-fertilizers and chemical fertilizers on sugarcane production and soil biological fertility. *Indian J. Sug. Tech.*, **30**(2): 98-10.
- Kumaraswamy, K.; Venu Reddy, R. and Babu, K. (1998). Cumulative effect of continuous cropping and manuring of sugarcane on organic matter and NPK status of the soil. *J. Indian Soc. Soil Sci.*, **46** (1): 47-49.
- Kuri, S. (2014). Response of sugarcane genotypes to organic nutrient management practices with special reference to jaggery production and quality. Master degree, Thesis. University of Agricultural Sciences, Dharwad-580005.
- Kuri, S. and Chandrashekar, C.P. (2015). Growth indices and yield of sugarcane genotypes under organic, inorganic and integrated nutrient management practices. *Karnataka J. Agric. Sci.*, **28**(3): 322-326.
- Lakshmi, C.S.R.; Sreelatha, T.; Rani, T.U.; Rao, S.R.K. and Naidu, N.V. (2011). Effect of organic manures on Soil fertility and productivity of sugarcane in north coastal zone of Andhra Pradesh. *Indian J. Agric. Res.*, **45**(4): 307-313.
- Lal, B. (1988). Yield, quality and root distribution pattern of sugarcane Co-1148 as influenced by method of planting. *Indian Sugar.*, **14**(1): 57, 59-60.
- Loganandhan, N.; Gujja, B.; Goud, V. and Natarajan, U.S. (2013). Sustainable sugarcane initiative (SSI): A methodology of more with less. *Sugar Tech.*, **15**(1): 98-102.
- Mahadevaswamy, M. and Martin, G.J. (2002). Production potential for wide row sugarcane inter-cropped with aggregatum onion. *Indian J. Agron.*, **47**(3): 366.
- Mahmood, A.; Ishfaq, M.; Iqbal, J. and Nazir, M.S. (2007). Agronomic performance and juice quality of autumn planted sugarcane as affected by flat, ditch and pit planting under different spatial arrangements. *Int. J. Agric. Biol.*, **9**: 167-169.
- Malavolta, E. (1994). Nutrient and fertilizer management in sugarcane. International Potash Institute Bulletin No. 14. International Potash Institute, Basel, Switzerland.
- Manimaran, S. and Kalyanasundaram, D. (2006). Effect of spacing, planting techniques, intercropping and nutrient management on yield and macronutrient uptake of sugarcane (Co 86032). *Indian Sugar*, **56**: 23-27.

- Maqsood, M.; Iqbal, M. and Tayyab, M. (2005). Comparative productivity performance of sugarcane sown in different planting patterns at farmer's field. *Pakistan J. Agric. Sci.*, **42**(3): 25-28.
- Marchiori, P.E.R.; Ribeiro, R.V.; Silva, L.D.; Machado, R.S.; Machado, E.C. and Scarpari, M.S. (2010). Plant growth, canopy photosynthesis and light availability in three sugarcane varieties. *Sugar Tech.*, **12**(2): 160-166.
- Mashiqaa, P.; Lekgaria, L. and Ngwako, S. (2011). Effect of plant density on yield and yield components of maize in Botswana. *World Sci. J.*, **7**: 173-179.
- Meena, B.L.; Singh, A.K.; Phogat, B.S. and Sharma, H.B. (2013). Effects of nutrient management and planting systems on root phenology and grain yield of wheat (*Triticum aestivum*). *Indian J. Agril. Sci.*, **83**(6): 627-632.
- Meena, B.S.; Meena, D.S. and Meena, S.N. (2013). Sustaining soil health and productivity of sugarcane (*Saccharum* species hybrid complex) plant-ratoon system through integrated use of organic and inorganic sources in clay loam soils of Rajasthan. *Indian J. Agron.*, **63**(4): 488-493.
- Misra, A.; Naidu, K.M.; Gupta, M.L. and Misra, A. (1990). Effect of row spacing and nitrogen level on ethanol production in sugarcane (*Saccharum officinarum*) at different ages of crop harvest. *Indian J. Agric. Sci.*, pp. 110-114.
- Mohanty, M.; Nanda, S.S. and Das, P.P. (2014). Introducing SSI (Sustainable Sugarcane Initiative) technology for enhanced cane production and economic returns in real farming situations under east coast climatic conditions of India. *Sugar Tech.*, **17**(2): 1-15.
- More, N.B.; Bhalerao, V.P.; Phalke, D.H.; Patil, A.V. and Bhoi, P.G. (2007). Nitrogen economy by using green manuring intercrops in pre seasonal sugarcane. *Indian Sug.*, pp. 39-45.
- More, N.B.; Potdar, D.S.; Shinde, N.J. and Pol, K.M. (2009). Fertilizer economy through double green manuring in pre-season (autumn) sugarcane. *Indian Sug.*, **59**(4): 17-23.
- Muhammad, Y.; Amir, A. and Mahboob, A. (2002). Response of two genotypes of sugarcane to different planting patterns. Pakistan Agricultural Research Council (PARC). *Asian J. Plant Sci.*, **1**: 346-348.
- Munsif, F.; Ali, K.; Khalidi, A.; Ali, A.; Ali, M.; Ahmad, M.; Ahmad, W.; Ahmad, I. and Basir, A. (2015). Influence of row spacing on weed density, biomass and yield of chip bud settling of sugarcane. *Pakistan J. Weed Sci. Res.*, **21**(1): 137-144.

- Murarkar, S.R.; Tayade, A.S.; Bodhade, S.N. and Ulemale, R.B. (1998). Effect of vermicompost on mulberry leaf yield. *J. Soil Crops*, **8**(1): 85-87.
- Nadeem, M.; Tanveer, A.; Sandhu, H.; Javed, S.; Safdar, M.E.; Ibrahim, M.; Shabir, M.A.; Sarwar, M. and Arshad, U. (2020). Agronomic and Economic Evaluation of Autumn Planted Sugarcane under Different Planting Patterns with Lentil Intercropping. *Agron.*, **10**(644): 1-24.
- Nadiger, S.; Sundara, B. and Nadagouda, B.T. (2017). Influence of wide row spacings and intercrops on sugarcane growth, yield and juice quality under drip irrigation in north-west Karnataka. *Int. J. Agril. Sci. Res.*, **7**(2): 111-120.
- Naidu, N.V. (2003). Status of sugarcane and strategies for increasing cane productivity in Andhra Pradesh. *Co-operative Sugars*, **34**(9): 717-722.
- Narasimha Rao, G. and Satyanarayan, Y. (1974). Studies in control of sett borne infection of red rot of sugarcane. *J. Res. Andhra Pradesh Agric. Univ.*, **1**: 83-86.
- Narendranath, M. (1992). Cost-effectiveness of transplanting nursery raised sugarcane bud-chip plants on commercial sugar plantations. *Proc. ISSCT Congr.*, **21**: 332-333.
- Nasir, M.N.; Qureshi, R.H.; Aslam, M. and Akhtar, J. (2000). Comparative studies on two selected sugarcane lines for differences in physiological traits. *Pakistan Sugar*, **6**: 52-61.
- Nazir, M.S.; Ghafoor, A.; Mahmood, K.; Nawaz, S. and Aslam, M. (1999). Morpho-qualitative traits of autumn planted sugarcane as influenced by seedling density and nutrient management. *Int. J. Agri. Biol.*, **4**: 238-240.
- Nazirkar, R.B. and Kamthe, N.D. (2012). Effect of INM for pre-seasonal sugarcane on growth, nutrient uptake, biochemical composition and soil properties. *Asian J. Soil Sci.*, **7**: 89-92.
- Nazirkar, R.B.; Domale, N. and Deshpande, A.N. (2010). Soil properties and sugarcane response as influenced by integrated nutrient management. *Asian J. Soil Sci.*, **5**(2): 411-414.
- Netsanet, A.; Abiy, G. and Tadesse, N. (2014). Influence of Intra-row Row Setts Spacing on Yield and Yield Components of Some Sugarcane Varieties at Finchaa Sugar Estate. *ARPJ. Sci. Technol.*, **4**(1): 39-45.
- Nosheen, N.E. and Ashraf, M. (2003). Statistical Analysis of Certain Traits that Influence Sugar Recovery of Selected Sugarcane Varieties. *Pakistan J. Bio. Sci.*, **6**: 99-104.

- Nyati, C. (1998). Fertilization. *In: Clowes, M.S.J. and Breakwell, W.L. (eds.) Zimbabwe Sugarcane Production Manual. Chiredzi: Cannon Press, pp. 110-113.*
- Orgeron, A.J. (2003). Planting Rate Effects on Sugarcane Yield Trials. MSc. Thesis, Louisiana State University and Agricultural College. USA.
- Paikaray, R.K.; Garnayak, L.M. and Rath, B.S. (2011). *In: Recent Development in Organic Farming. Department of Agronomy, Orissa University of Agriculture and Technology, Bhubaneswar, pp. 375-385.*
- Parham, J.A.; Deng, S.P.; Raun, W.R. and Johnson, G.V. (2002). Longterm cattle manure application in soil. 1. Effect on soil phosphorus levels. Microbial biomass C and dehydrogenase and phosphatase activities. *Boil Fert. Soils*, **35**: 328-337.
- Patel, D. and Chaudhari, M. (2018). Integrated application of organic, inorganic and biological fertilizers for enhancing sugarcane productivity and improving soil health in plant Ratoon cycle. *J. Pharm. Phytochem.*, **7**(3): 1586-1589.
- Patel, D. and Patel, R. (2014). Influence of sett size, seed rate and sett treatment on yield and quality of sugarcane. *The Bioscan.*, **9**(1): 55-57.
- Patel, D.; Raj, V.C.; Tandel, B.; Patel, B.; Patel, D.U. and Surve, V. (2014). Influence of planting distance and variety on growth of sugarcane and weed population under mechanization. *Academic Res. Multidis*, **2**(6): 34-41.
- Patel, F.; Alvarez, M.J.; Phillips, J.D. and Giland, B.R. (2002). Sugarcane as Cattle Feed: Production and Utilization. IFAS, US department of Agriculture, USA.
- Pathak, A.K. and Ghosh, T.S. (1996). Nutrient management in rice-wheat cropping system. *Fert. News*, **41**: 55-58.
- Patil, R.P. (2008). Physiological approaches for drought tolerance in sugarcane (*Saccharum officinarum* L.). PhD dissertation in Crop Physiology. Departemant of Crop Physiology College of Agriculture Dharwad, University of Agriculture Sciences, Dharwad.
- Patnaik, J.; Singh, S.; Sarangi, D. and Nayak, P. (2016). Assessing Potentiality of Bud Chip Technology on Sugarcane Productivity, Profitability and Sustainability in Real Farming Situations Under South East Coastal Plain Zone of Odisha, India. *Sugar Tech.*, **19**(4): 373-377.
- Pawar, M.W.; More, D.B.; Amodkar, V.T. and Joshi, S. (2005). Effect of inter settling spacing on sugarcane yield and quality. *Indian J. Sugar Tech.*, **7**: 87-89.

- Piper, C.S. (1966). Soil and Plant Analysis. Hans Publishers, Bombay, India, pp. 368-370.
- Preecha, N. (2006). Influence of spacings on growth parameters and sugar yield of F140 and F156 sugarcane varieties. *AGRIS*. FAO. Bangkok, Thailand.
- Power, F.; Willis, W.O.; Grunes, D.L. and Reichman, G.A. (1967). Effect of soil temperature, phosphorus and plant age on growth analysis of barley. *Agron. J.*, **59**: 231-23.
- Rabindra, B.; Narayan Swamy, G.V.; Janardhan, N.A. and Shivanagappa (1985). Long range effect of manures and fertilizer on soil physical properties and yield sugarcane. *J. Indian Soc. Soil Sci.*, **33**(1): 704-706.
- Radford, R.J. (1967). Growth analysis formulae-their use and abuse. *Crop Sci.*, **7**: 171-175.
- Rai, R.K.; Tripathi, N.; Gautam, D. and Singh, P. (2017). Exogenous Application of Ethrel and Gibberellic Acid Stimulates Physiological Growth of Late Planted Sugarcane with Short Growth Period in Sub-tropical. *Indian J. Plant Growth Regul.*, **36**: 472-486.
- Rajula, S.T. and Ramanjaneyulu, S. (2014). Socio economic performance analysis of sugarcane cultivation under sustainable sugarcane Initiative method. *Indian Res. J. Ext. Edn.*, **14**(3): 93-98.
- Rajulashanthy, T. and Muthusamy, G.R. (2012). Wider row spacing in sugarcane: A socio-economic performance analysis. *Sugar Tech.*, **14**(2): 126-133.
- Rakkiyappan, P.; Thangavelu, S.; Malathi, R. and Radhamani, R. (2001). Effect of biocompost and enriched press mud sugarcane yield and quality. *Sugar Tech.*, (3): 92-96.
- Ramaiah, B.B.; Narasimha Rao, G. and Prasad, G.H. (1977). Elimination of internodes in sugarcane seed Piece. *Proc. Inter. Soc. Sugar Cane Technol.*, pp. 1509-1513.
- Ramesh, T.; Chinaswamy, C. and Sankaran, N. (2002). Influence of integrated nitrogen and phosphorous management on cane productivity and soil fertility status in sugarcane. *Cooperative Sugar*, **34**(1): 37-39.
- Rao, K. K. (1989). In : *75 years of Agricultural Research at Anakapalle (1913-1988)*. Regional Agricultural Research Station, Anakapalle, A.P.A.U., Andhra Pradesh, pp. 128-176.
- Rao, P.N. (1990). Recent Advance in Sugarcane. M/S the K.C.P. Limited, Vuyyuru-India.

- Raskar, B.S. and Bhoi, P.G. (2003). Yield attributes of sugarcane as influenced by intra-row spacings, fertilizer levels and planting materials. *Indian Sugar.*, **53**(5): 327-331.
- Rehman, A.; Ehsanullah, R.A. and Abdul, J. (2013). Interactive study of row spacings and foliar application of macro and micro-nutrients on growth, yield and quality of sugarcane (*Saccharum officinarum* L.). *Pakistan J. Bot.*, **45**(2): 427-433.
- Roodagi, L.L.; Itanal, C.J.; Biradar, D.P. and Angadi, S.A. (2001). Leaf area index, light transmission ratio and sugar yield of sugarcane as influenced by planting methods and intercropping system. *Indian Sugar*, **26**(10): 39-45.
- Saha, S.; Prakash, V.; Kundu, S.; Kumar, N. and Mina, B.L. (2008). Soil enzymatic activity as affected by long-term application of farmyard manure and mineral fertilizer under a rainfed soybean–wheat system in NW Himalaya. *European J. Soil Biol.*, **44**: 309-315.
- Saini, S.K.; Shashank, T.; Dheer, S.; Sinha, S.K. and Vijendra, S. (2006). Nutrient (NPK) uptake influenced by integrated nutrient management in spring planted sugarcane grown in sugarcane based cropping sequence. *Indian Sugar*, **56**(9): 67-72.
- Saini, S.P.; Sidhu, A.S. and Singh, P. (2012). Economics and yield potential of single bud planted autumn and spring sugarcane (*Saccharum* spp. Hybrid) intercropped with pulses. *Indian J. Sugar Tech.*, **27**(1): 7-10.
- Samant, T.K. (2017). Bud chip method: A potential technology for sugarcane (*Saccharum officinarum*) cultivation. *J. Med. Plants. Stud.*, **5**(3): 355-357.
- Sarala, V.N. (2017). Influence of planting methods, age of the seedlings and nutrient management on yield and quality of sugarcane raised from bud chip seedlings in sandy loam soils of Andhra Pradesh. *Int. J. Clin. Biol. Sci.*, **2**(1): 44-49.
- Sarma, A. (2016). Agricultural Statistics for Field and Laboratory Analysis. Kalyani Publishers, New Delhi.
- Saviozzi, A.; Bufalino, P.; Minzi, L.R. and Riffaldi, R. (2002). Biochemical activities in a degraded soil restored by two amendments: a laboratory study. *Biol. Fert. Soils*, **35**: 96-119.
- Senesi, N.; Plaza, C.; Brunetti, G. and Polo, A. (2007). A comparative survey of recent results on humic-like fractions in organic amendments and effects on native soil humic substances. *Soil Biol. Biochem.*, **39**(6): 1244-1262.

- Shahid, Z.; Ahmed, A.U. and Javeed, H.M.R. (2011). Integrated application of fertilizers and biocane (organic fertilizers) to enhance the productivity and juice quality of autumn planted sugarcane (*Saccharum officinarum* L.). *African J. Agril. Res.*, **6**(21): 4857-4861.
- Sharma, B.L.; Prakash, V.; Singh, S.; Shrivastava, P.W. and Singh, D.N. (2006). Integrated nutrient management in sugarcane: performance of FYM and press mud cake with inorganic N on yield and quality indices of slow growing cultivar cos-8436 in calcareous soil. *Co-op. Sug.*, **37**(8): 47-52.
- Sharma, B.L.; Singh, S.; Prakash, V., Mishra, A.K.; Srivatava, P.N.; Singh, D.N. and Singh, S.B. (2005). Integrated nutrient management in sugarcane: Performance of FYM, Biocompost and press mud cake with inorganic N on growth and quality indices. *Cooperative Sugar*, **36**(12): 993-998.
- Sharma, R.A. (1984). Effect of pre-monsoon irrigation and inter-row spacing on yield and quality of sugar cane. *JNKVV Res. J.*, **16**(2): 136-141.
- Shridevi, B.A. and Chandrasekhar, C.P. (2004). Effect of nutrient management practices and genotypes on yield and quality of sugarcane and jaggery. Conference on National seminar on “Integrated crop management in sugarcane for increasing cane sugar and jaggery yield”, Andra University Campus, Vishakapatnam, India.
- Shridevi, B.A.; Chandrashekar, C.P. and Patel, S.B. (2016). Performance of sugarcane genotypes under organic, inorganic and integrated nutrient management systems. *Imp. J. Interd. Res.*, **2**(9): 970-979.
- Shrivastava, A.K.; Upadhyay, V.B.; Gautam, D.S.; Sarvade, S. and Sahu, R.K. (2018). Effect of integrated nutrient management on growth and productivity of *Withania somnifera* (L.) Dunal in Kymore Plateau and Satpura hills of Madhya Pradesh, India. *Arch. Agril. Emt. Sci.*, **3**(2): 202-208.
- Shukla, S.K. and Lal, M. (2003). Effect of sett size, planting method and moisture regime on growth and yield of sugarcane. *Indian J. Agric. Sci.*, **73**(10): 534-537.
- Simões, M.S.; Rocha, J.V. and Lamparell, R.A.C.L. (2005). Spectral variables, growth analysis and yield of sugarcane, *Sci. Agric. (Piracicaba, Braz.)*. **62**(3): 199-207.
- Singels, A. and Smit, M.A. (2002). The effect of row spacing on an irrigated plant crop of sugarcane variety NCO376. *Proc. S Afr Sug Technol Ass*, 76.
- Singh, A.K.; Lal, M. and Singh, S.N. (2011). Agronomic performance of new sugarcane genotypes under different planting geometries and N levels. *Indian J. S. Tech.*, **26**(1): 6-9.

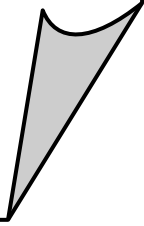
- Singh, A.P.; Singh, K.T.M. and Sakal, R. (1999). In: *Proc. National Symposium on Management of Micronutrient Deficiencies in Alluvial Plains*. August 18-20, Lucknow.
- Singh, G.B. and Yadav, D.V. (1992). Integrated nutrient supply system in sugarcane and sugarcane based system. *Fert. News*, **37**: 15-22.
- Singh, K.P.; Suman, A. and Singh, P.N. (2007). Yield and soil nutrient balance of a sugarcane plant-ratoon system with conventional and organic nutrient management in sub-tropical India, *Nutr. Cycl. Agroecosyst*, **79**: 209-219.
- Singh, O.P.; Singh, G.; Singh, B.B. and Sharma, M.S. (1995). Effect of pressmud and fertilizer on yield and quality of plant and ratoon sugarcane in flood-prone areas. *Indian J. Agron.*, **40**(3): 469-473.
- Singh, R. and Agarwal, S.K. (2001). Analysis of growth and productivity of wheat (*Triticum aestivum* L.) in relation to levels of FYM and nitrogen. *Indian J. Plant Phys.*, **6**(3): 279-283.
- Sinha, S.K.; Jha, C.K.; Kumar, V.; Kumari, G. and Alam, M. (2014). Integrated effect of bio-methanated distillery effluent and bio-compost on soil properties, juice quality and yield of sugarcane in Entisol. *Sugar Tech.*, **16**(1): 75-79.
- Soomro, A. F.; Arain, M.Y.; Panhwar, R.N.; Rajput, M.A. and Gujar, N. (2009). Effect of spacing and seed placement on yield and yield contributing characters of sugarcane variety thatta-10 under agro ecological condition of thatta. *Pakistan J. S.*, **61**(2): 110-115.
- Soomro, A.F.; Tunio, S.; Fateh, C.O. and Rajper, I. (2013). Integrated effect of inorganic and organic fertilizers on the yield and quality of sugarcane (*Saccharum officinarum* L.). *Pakistan J. Bot.*, **45**(4): 1339-1348.
- Soomro, F.A.; Tunio, S.; Oad, F.C.; Rajper, I.; Khuhro, M. and Arain, M.Y. (2012). Effect of Supplemental Inorganic NPK and Residual Organic Nutrients on Sugarcane Ratoon Crop. *Int. J. Sci. Engg. Res.*, **3**(10): 1-11.
- Spencer, G.L. and Meade, G.P. 1955. *Cane Sugar Hand Book*. J. Wiley and Sons, N.Y.
- Srivastava, T.K.; Lal, M.; Singh, K.P.; Suman, A. and Kumar, P. (2009). Enhancing soil health and sugarcane productivity in a plant-ratoon system through organic nutrition modules in subtropics. *Indian J. Agril. Sci.*, **79**(5): 346-350.
- Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for the determination of available nitrogen in soils. *Current Science* **25**: 256-260.

- Sugeerthi, S.; Jayachandran, M. and Chinnusamy, C. (2018). Effect of Planting Materials and Integrated Nutrient Management on Yield of Sugarcane Seed Crop. *Madras Agric. J.*, **105**(4-6): 141-146.
- Suggu, A.G.; Ahmad, E.; Himayatullah, H.; Ayaz, M.; Ahmad, H.K. and Aslam, M. (2010). Morphological responses of autumn planted sugarcane to planting geometry and nutrient management on different soils under arid conditions. *Pakistan Sug. J.*, **25**(01): 2-9.
- Swamy, R.K.; Rao, M.T.K.V.V and Rao, P.L.U.V. (1999). Biofertilizers for sugarcane. *Biofer. Newslett.*, **7**(1): 8-11.
- Tadesse, A.; Kim, H. and Debela, A. (2015). Calibration of nitrogen fertilizer for quality protein maize (*Zea mays* L.) based on in-season estimated yield using a handheld NDVI sensor in the central rift valley of Ethiopia. *Asia Pacific J. Energy Emt.*, **2**: 25-32.
- Teruel, D.A.; Baarbieri, V. and Ferraro, L.A. (1997). Sugarcane leaf area index modeling under different soil water conditions, *Sci. Agric. Piracicaba.*, **54**: 39-44.
- Thakur, S.K.; Jha, C.K.; Alam, M. and Singh, V. P. (2012). Productivity, quality and soil fertility of sugarcane (*Saccharum* spp. complex hybrid) plant and ratoon grown under organic and conventional farming system. *Indian J. Agril. Sci.*, **82**: 896-899.
- Thomas, J.R.; Salinas, F.G. and Namken, L.N. (1977). Growth and yield of sugarcane as affected by row spacing. *Proc. Amer. Soc. Sug. Tech.*, pp. 129-135.
- Tianco, A.P (1995). Preliminary Observations on Using Single eye Transplants and Hole Planting to Reduce Cost of Conventional Planting. *Proc. of 11th Intern. Soc. Sugarcane Technol.*, **21**: 136-142.
- Tolanur, S.I. and Badanur, V.P. (2003). Effect of integrated use of organic manure, green manure and fertilizer nitrogen on sustaining productivity of *rabi* sorghum- chickpea system and fertility of vertisol. *J. Indian Soc. Soil Sci.*, **51**(1): 41-44.
- Trivedi, B.S.; Patel, H.S.; Patel, G.G. and Naik, P.L. (1997). Effect of FYM, press mud and PSB. *Proc. 46th Ann. Conv. D.S.T.A., Pune. Part I*, pp. 165- 170.
- Tyagi, S. (2005). Studies on integrated nutrient management in sugarcane ratoon system. PhD dissertation. G.B. Pant University of Agriculture and Technology.

- Tyagi, S.; Kumar, V.; Saini, S.K.; Pathak, S.K. and Kumar, B. (2012). Impact of INM strategies on growth, yield, quality and profitability as well as soil fertility status in sugarcane. *Progr. Agric.*, **12**(1): 110-117.
- Uddin, S.M.M.; Murayama, S.; Ishimine, Y.; Tsuzuki, E. and Harada, J. (1995). Studies on sugarcane cultivation. *Japan J. Crop Sci.*, **64**(4): 747-753.
- Umesh, U.N.; Kumar, Vipin, A.M.; Sinha, S.K. and Khusboo, V. (2013). Integrated effect of organic and inorganic fertilizers on yield, quality parameters and nutrient availability in calcareous soil. *Sugar Tech.*, **15**: 365-369.
- Van Dillewijn, C. (1952). The Chronica Botanica Co. Waltham, USA, p. 352.
- Vanlauwe, B.; Wendt, J. and Diels, J. (2001). Combined application of organic matter and fertilizer. *In: Sustaining Soil Fertility in West-Africa*. Tian, G., Ishida, F. and Keatinge, J.D.H. (eds.). SSSA Special Publication Number 58, Madison, USA, pp. 247-280.
- Venkata Krishnan, D. and Ravichandran, M. (2012). Effect of integrated nutrient management on sugarcane yield and soil fertility on an Ultic Haplustalf. *J. Indian Soc. Soil Sci.*, **60**(1): 74-78.
- Verma, R.S. (2004). Sugarcane Projection Technology in India. Lucknow: International Book Distributing Co. (Need to add).
- Virdia, H.M. and Patel, C.L. (2010). Integrated nutrient management for sugarcane plant-ratoon system. *Indian J. Agron.*, **55**: 147-151.
- Walkey, A. and Black, C.A. 1934. An examination of the method for determination of soil organic matter and proposed modification of the chromic acid titration method. *Soil Science* **37**: 29-39.
- Wani, S.A.; Chand, S. and Ali, T. (2013). Potential use of *Azotobacter chroococcum* in Crop production: an overview. *Curr. Agric. Res. J.*, **1**(1): 35-38.
- Yadav, D.V. (2000). Organic manuring in sugarcane prospects and retenespects. *Indian Sug.*, **49**(2): 979-988.
- Yadav, R.L. (1991). Hight Population Density Management in Sugarcane. *Proc. Indian Natn. Sci. Acad.*, **B57**(3&4): 175-182.
- Yadav, R.L. and Prasad, S.R. (1992). Conserving the organic matter content of the soil to sustain sugarcane yield. *Expt. Agric.* **28**: 57-62.
- Yadav, R.L. and Prasad, S.R. (1997). Maximizing sugarcane yield by increasing plant population density, minimizing NO₃-N leaching and improving soil organic matter in different crop rotations. *J. Agron. Crop Sci.*, **178**: 117-123.

- Yadav, S.P.; Singh, S.C.; Yadav, S.; Yadav, S.K.; Tiwari, A.K. and Sharma, B.L. (2018). Integrated Nutrient Management Approaches for Enhancing Production Potential and Sustainability of Sugarcane (*Saccharum* spp. hybrid) Plant–Ratoon System in North Region of India. *Sugar Tech.* doi: 10.1007/s12355-018-0641-z.
- Yaduvanshi, H.S.; Tripathi, B.R. and Kanwar, B.S. (1985). Effect of continuous manuring on some soil properties of Alfisol. *J. Indian Soc. Soil Sci.*, **33**: 700-703.
- Yaduvanshi, N.P.S. and Yadav, D.V. (1992). Effect of direct, residual and cumulative application of press mud with nitrogen on soil properties and on yield and quality of sugarcane. *Indian J. Sugar Tech.*, **7**(1): 33-39.
- Zafar, M.A.; Tanveer, Z.A.; Cheema and Ashraf, M. (2010). Weed-crop competition effects on growth and yield of sugarcane planted using two methods. *Pakistan J. Bot.*, **42**: 815-823.
- Zende, G.K.; Ruikar, S.K. and Joshi, S.N. (1998). Effect of application of vermi compost along with chemical fertilizers on sugarcane yield and juice quality. *Indian Sug.*, **48**(1): 357-369.

Annexures... 



ANNEXURE – I (a)

Weekly weather report during the period of experimentation (2017-18)

Standard Meteorological Week	Period	Temperature (°C)		Relative humidity (%)		RF (mm)	BSSH (hr)
		Max	Min	Morn	Eve		
8	15 Oct - 21 Oct	31.3	23.2	97	80	30.2	3.7
9	22 Oct - 28 Oct	27.6	20.3	97	79	57.0	4.9
10	29 Oct - 4 Nov	28.1	18.5	93	74	7.0	7.1
11	5 Nov - 11 Nov	30.1	16.2	93	65	0.0	9.2
12	12 Nov - 18 Nov	28.2	16.3	96	67	0.3	5.8
13	19 Nov - 25 Nov	28.7	17.1	97	68	7.0	7.4
14	26 Nov - 2 Dec	26.0	13.6	99	70	7.4	6.6
15	3 Dec - 9 Dec	26.5	11.2	99	66	0.0	6.3
16	10 Dec -16 Dec	25.7	16.5	98	77	0.0	1.3
17	17 Dec - 23 Dec	25.2	12.5	100	68	0.0	5.5
18	24 Dec- 31 Dec	25.8	11.1	100	65	0.0	7.3
19	1 Jan - 7 Jan	23.7	11.8	98	73	0.5	4.6
20	8 Jan - 14 Jan	23.2	8.9	98	65	0.0	6.9
21	15 Jan -21 Jan	25.2	11.8	99	67	0.0	4.8
22	22 Jan - 28 Jan	24.1	12.5	98	73	2.2	3.2
23	29 Jan - 4 Feb	22.6	12.2	98	72	1.0	1.3
24	5 Feb - 11 Feb	22.5	13.2	99	73	1.4	2.1
25	12Feb - 18 Feb	26.7	11.6	95	55	10.7	7.3
26	19Feb - 25 Feb	26.4	14.5	96	63	4.3	3.2
27	26 Feb - 4 Mar	23.7	15.6	97	79	56.3	1.5
28	5 Mar - 11 Mar	27.4	15.2	94	60	3.2	2.5
29	12 Mar - 18 Mar	26.9	15.8	95	66	13.8	2.4
30	19 Mar - 25 Mar	28	15.5	95	60	11.3	4.7
31	26Mar-1st Apr	28.7	17.5	93	57	3.1	5.5
32	2 Apr - 8 Apr	31.5	18.4	92	56	20.1	4.5
33	9 Apr - 15 Apr	28.2	19.2	96	69	37.6	3.8
34	16 Apr - 22 Apr	29.1	19.9	93	69	43	3.7
35	23 Apr - 29 Apr	30.4	20	85	66	11.1	5.9
36	30 Apr - 6 May	28.6	20.5	93	72	39.7	3.1
37	7 May - 13 May	28.1	21.2	96	77	25.5	2.8
38	14 May - 20 May	32	22.1	90	64	73.4	7.1
39	21 May - 27 May	33.2	24.1	91	72	86.3	3.7
40	28 May - 3 Jun	31.1	24.1	94	73	17.2	4.1
41	4 Jun - 10 Jun	34.5	25.1	92	65	72.2	6.7

Standard Meteorological Week	Period	Temperature(oC)		Relative humidity (%)		RF(mm)	BSSH(hr)
		Max	Min	Morn	Eve		
42	11 Jun - 17 Jun	31.7	25	97	82	99.4	1
43	18 Jun - 24 Jun	32.5	25.3	95	83	35.2	3.1
44	25 Jun - 1 July	33.3	24.8	94	74	25.5	3.5
45	2 July - 8 July	32.3	25.6	93	80	110.6	2.4
46	9 July - 15 July	34.3	25.8	92	71	46.3	5.2
47	16 July - 22 July	35	26.9	93	71	3.5	5.9
48	23 July - 29 July	33.6	25.8	94	75	50.3	3.5
49	30 July - 5 Aug	31.7	25.5	96	78	99.1	2.5
50	6 Aug - 12 Aug	34.8	26	92	72	70.9	5.3
51	13 Aug - 19 Aug	34.1	26.426	95	73	65.2	5.9
52	20 Aug - 26 Aug	33.5	25.4	94	79	127.5	3.4
53	27 Aug - 2 Sep	32.8	25.2	97	73	127.9	4
54	3 Sep - 9 Sep	34.1	25.8	89	71	71	4.9
55	10 Sep - 16 Sep	31.4	24.4	93	81	137.8	2.8
56	17 Sep - 23 Sep	33	25.3	92	74	9.5	6
57	24 Sep - 30 Sep	30.3	23.9	99	83	55.5	1.1
58	1 Oct - 7 Oct	30.6	23	97	69	4	5.8
59	8 Oct - 14 Oct	28.7	21.3	97	78	12.8	3.6
60	15 Oct - 21 Oct	29	19.8	94	71	0.6	4.6
61	22 Oct - 28 Oct	30.7	18.9	97	61	0	7.1
62	29 Oct - 4 Nov	28.9	18.1	95	65	0	6.1
63	5 Nov - 11 Nov	25.9	16.1	98	66	19.3	5.7
64	12 Nov - 18 Nov	26.4	15.6	98	70	13.1	4.9
65	19 Nov - 25 Nov	25.6	13.3	98	67	0	6.4
66	26 Nov - 2 Dec	26.9	11.9	99	60	0	7.7
67	3 Dec - 9 Dec	25.9	11.1	98	59	0	7.2
68	10 Dec -16 Dec	26.4	9.7	95	53	0	6.9
69	17 Dec - 23 Dec	22.7	12.9	99	77	29.6	4.1
70	24 Dec- 31 Dec	24.2	9.7	98	65	0	7.5
71	1 Jan - 7 Jan	23.3	8.2	95	61	0.6	7.7

Source: Meteorological observatory unit, SRS, Buralikson

APPENDIX I (b)

Weekly weather report during the period of experimentation 2018-19

Standard Meteorological Week	Period	Temperature (°C)		Relative humidity (%)		RF (mm)	BSSH (hr)
		Max	Min	Morn	Eve		
8	15 Oct - 21 Oct	29.0	19.8	94	71	0.6	4.6
9	22 Oct - 28 Oct	30.7	18.9	97	61	0.0	7.1
10	29 Oct - 4 Nov	28.9	18.1	95	65	0.0	6.1
11	5 Nov - 11 Nov	25.9	16.1	98	66	19.3	5.7
12	12 Nov - 18 Nov	26.4	15.6	98	70	13.1	4.9
13	19 Nov - 25 Nov	25.6	13.3	98	67	0.0	6.4
14	26 Nov - 2 Dec	26.9	11.9	99	60	0.0	7.7
15	3 Dec - 9 Dec	25.9	11.1	98	59	0.0	7.2
16	10 Dec -16 Dec	26.4	9.7	95	53	0.0	6.9
17	17 Dec - 23 Dec	22.7	12.9	99	77	29.6	4.1
18	24 Dec- 31 Dec	24.2	9.7	98	65	0.0	7.5
19	1 Jan - 7 Jan	23.3	8.2	95	61	0.6	7.7
20	8 Jan - 14 Jan	24.1	9.1	96	62	6.6	7.5
21	15 Jan -21 Jan	25.4	8.1	96	57	0.0	7.4
22	22 Jan - 28 Jan	25.9	10.3	93	61	0.0	6.4
23	29 Jan - 4 Feb	25.0	10.2	94	58	3.5	6.1
24	5 Feb - 11 Feb	25.8	12.1	95	60	9.2	5.8
25	12Feb - 18 Feb	27.2	12.2	90	59	8.2	5.6
26	19Feb - 25 Feb	21.3	14.2	98	76	17.9	1.5
27	26 Feb - 4 Mar	24.5	12.2	95	61	5.3	4.6
28	5 Mar - 11 Mar	23.5	15.1	94	68	18.5	2.5
29	12 Mar - 18 Mar	29	17.3	90	58	0	3.3
30	19 Mar - 25 Mar	26.8	15.8	90	63	34.3	3.8
31	26 Mar - 1 Apr	29.3	17.5	90	61	21.9	4.3
32	2 Apr - 8 Apr	24.7	18.2	93	74	28	3.3
33	9 Apr - 15 Apr	29.7	19.7	93	64	27.9	5.2
34	16 Apr - 22 Apr	30.2	20	91	71	44.1	4.3
35	23 Apr - 29 Apr	32.4	21.4	89	68	32.5	4.6
36	30 Apr - 6 May	25.9	21.1	98	83	192.2	1.7
37	7 May - 13 May	26.1	20.6	96	84	51.6	1.5
38	14 May - 20 May	28.3	21.2	95	79	52.9	1.9
39	21 May - 27 May	28.4	22.5	93	80	75.9	1.4
40	28 May - 3 Jun	31.2	23.7	90	67	14	4.8
41	4 Jun - 10 Jun	32.2	24.9	93	74	48.8	2.6

Standard Meteorological Week	Period	Temperature (°C)		Relative humidity (%)		RF (mm)	BSSH (hr)
		Max	Min	Morn	Eve		
42	11 Jun - 17 Jun	33.7	25.9	86	71	55.9	3.6
43	18 Jun - 24 Jun	32.8	25.6	90	76	149.5	4.5
44	25 Jun - 1 July	32.7	25.4	90	76	65.4	3.8
45	2 July - 8 July	33.76	25.74	95.29	75.57	194.9	3.86
46	9 July - 15 July	29.31	25.07	92.57	90	65.4	0
47	16 July - 22 July	32.61	25.46	89.29	79.14	43.7	2.69
48	23 July - 29 July	31.38	25.16	92	78.29	74.2	1.76
49	30 July - 5 Aug	31.9	25.4	93	78	78.3	3.5
50	6 Aug - 12 Aug	34.8	26.9	90	70	4.4	6.7
51	13 Aug - 19 Aug	34.5	25.8	91	74	84.1	6.9
52	20 Aug - 26 Aug	33.4	26.6	90	68		
53	27 Aug - 2 Sep	34.3	26	94	75	48	6.5
54	3 Sep - 9 Sep	34.1	25.1	95	73	86.8	5.2
55	10 Sep - 16 Sep	34.1	25.1	97	76	110.6	2.9
56	17 Sep - 23 Sep	34.2	24.6	96	74	62.2	5.3
57	24 Sep - 30 Sep	28.4	22.4	97	81	108.1	2.6
58	1 Oct - 7 Oct	30.8	23.3	98	76	90.9	4.4
59	8 Oct - 14 Oct	30.9	22.3	97	69	61.3	5.3
60	15 Oct - 21 Oct	32.5	21.8	97	65	0.9	6.6
61	22 Oct - 28 Oct	25.8	20	98	80	98.6	2.8
62	29 Oct - 4 Nov	30.4	18.5	95	63	0	8.1
63	5 Nov - 11 Nov	28.5	19.3	97	74	11.5	4.5
64	12 Nov - 18 Nov	29	18.3	98	66	0	6.1
65	19 Nov - 25 Nov	27.4	15.7	98	67	0	6.7
66	26 Nov - 2 Dec	27.3	14.6	99	65	1.3	5.7
67	3 Dec - 9 Dec	25.2	9.9	98	58	0	8.2
68	10 Dec - 16 Dec	24.1	11.2	99	64	0	4.4
69	17 Dec - 23 Dec	23.6	11.1	100	69	0	4.1
70	24 Dec - 31 Dec	22.4	8.4	100	61	0	5.2
71	1 Jan - 7 Jan	20.7	10.4	100	74	6.2	2.1

Source: Meteorological observatory unit, SRS, Buralikson

ANNEXURE II

Calendar of field operations for *autumn planted sugarcane*

SI No	Particulars of operation	Date of operation	
		2017-18	2018-19
1	Ploughing, Harrowing, leveling, Trenching, Hoeing of experimental plot.	19.09.2017 8.10, 2017 12, 10.2017 13.10.2017	18.09.2018 7.10.2018 11.10.2018 13.10.2018
2	Final land preparation and layout of the experiment	15.10.2017	14.10.2018
3	Drainage/ Irrigation channel	16.10.2017	14.10.2018
3	FYM, vermicompost, enriched compost and fertilizer application (conventional method)	17.10.2017	15.10.2018
4	Planting of 3 budded setts in main field/ Planting of bud chip nursery	18.10.2017	16.10.2018
5	Sowing of cowpea	20.10.2017	18.10.2018
6	In-situ incorporation of cowpea	28.12.2018	26.12.2019
7	Transplanting in the main field	14.11.2017	12.11.2018
8	Irrigation	16.11.2017 18.12.2017	14.11.2018 17.12.2018
9	Gap filling	24.11.2017	22.11.2018
10	Manual weeding	17.01.2018 16.03.2018	16.01.2019 14.03.2019
11	Earthing- up	18.01.2018 19.03.2018	17.01.2019 16.03.2019
12	Insecticide spray (Chlorophyris 20EC, and Malathion 50 EC)	18.02.2018 7.08.2018	2.02.2019 3.08.2019
13	Harvesting	04.01.2019	03.01.2020

ANNEXURE III (a)

Common cost of cultivation under the conventional method (M₁)

Sl No	Item/ operation	Unit	Cost/Unit (₹)		Total cost /ha (₹)	
			2017-18	2018-19	2017-18	2018-19
1	Land preparation					
	Ploughing, 15l/unit	1	72/litre	73.42/litre	1080.00	1101.30
	Harrowing, 15 l/unit	1	72/litre	73.42/litre	1080.00	1101.30
	Trenching , 15 l/unit	1	-do-	73.42/litre	1080.00	1101.30
	Hoeing	9 mds	250/ md		2250.00	2250.00
2	Sett preparation & planting					
	Quantity of sett	75q	350/q	350/q	26,250.00	26,250.00
	Sett preparation	10 mds	250/ md	250/ md	2,500.00	2,500.00
	Planting	28 mds	250/ md	250/ md	7000.00	7000.00
3	Plant protection measure					
	Chlorophyris, Malathion and		918	918	918.00	1135.00
	Required manpower	3mds	250/ md	250/ md	750.00	750.00
4	Earthing up	35 mds	250/ md	250/ md	8,750.00	8,750.00
5	Manual weeding	20 mds	250/ md	250/ md	5000.00	5,000.00
6	Irrigation				2500.00	3000.00
7	Harvesting	85 mds	250/ md	250/ md	21,250.00	21,250.00
Total					80,4,08.00	81,1,88.00

ANNEXURE III (b)

Common cost of cultivation under the planting of bud chip seedlings at 90 cm x 60 cm (M₂)

Sl No	Item/ operation	Unit	Cost/Unit (₹)		Total cost /ha (₹)	
			2017-18	2018-19	2017-18	2018-19
1	Land preparation					
	Ploughing, 15l/unit	1	72/litre	73.42/litre	1080.00	1101.30
	Harrowing, 15 l/unit	1	72/litre	73.42/litre	1080.00	1101.30
	Trenching , 15 l/unit	1	-do-	73.42/litre	1080.00	1101.30
	Hoeing	9 mds	250/ md	250/ md	2250.00	2250.00
2	Nursery raising					
	Quantity of setts	20q	350/q	350/q	7000.00	7000.00
	Plastic tray/bottle				5000.00	5000.00
	Growing media(vermicompost)	19q	10/Kg	10/kg	19000.00	19000.00
	Cutting of bud chip	20 mds	250/ md	250/ md	5000.00	5000.00
	Bud chip treatment with fungicide	4 mds	250/ md	250/ md	1000.00	1000.00
	Planting of bud chip in nursery	25 mds			6250.00	6250.00
	Watering and maintenance of seedlings in nursery	16 mds	250 /md	250 /md	4000.00	4000.00
	Transplanting of seedling in main field	30 mds	250/ md	250/ md	7500.00	7500.00
	Gap filling	4 mds	250 /md	250 /md	1000.00	1000.00
3	Plant protection measure					
	Chlorophyris, Malathion and				918.00	1135.00
	Fungicide				1000.00	1150.00
	Required manpower	3mds	250/ md	250/ md	750.00	750.00
4	Earthing up	35 mds	250/ md	250/ md	8,750.00	8,750.00
5	Manual weeding	20 mds	250/ md	250/ md	5000.00	5,000.00
6	Irrigation				2500.00	3000.00
7	Harvesting	100 mds	250/ md	250/ md	25000.00	25000.00
Total					105158.00	106089.00

ANNEXURE III (c)

Common cost of cultivation under the planting of bud chip seedlings at 120 cm x 60 cm (M₃)

Sl No	Item/ operation	Unit	Cost/Unit (₹)		Total cost /ha (₹)	
			2017-18	2018-19	2017-18	2018-19
1	Land preparation					
	Ploughing, 15l/unit	1	72/litre	73.42/litre	1080.00	1101.30
	Harrowing, 15 l/unit	1	72/litre	73.42/litre	1080.00	1101.30
	Trenching , 15 l/unit	1	-do-	73.42/litre	1080.00	1101.30
	Hoeing	9 mds	250/ md	250/ md	2250.00	2250.00
2	Nursery raising					
	Quantity of setts	14.28q	350/q	350/q	5000.00	5000.00
	Plastic tray/bottle				3500.00	3500.00
	Growing media(vermicompost)	13.4	10/kg	10/kg	13400.00	13400.00
	Cutting of bud chip	mds	250/ md	250/ md	4000.00	4000.00
	Bud chip treatment with fungicide	2 mds	250/ md	250/ md	500.00	500.00
	Planting of bud chip in nursery	20 mds	250/ md	250/ md	5000.00	5000.00
	Watering and maintenance of seedlings in nursery	12mds	250/ md	250/ md	3000.00	3000.00
	Transplanting of seedling in main field	30 mds	250/ md	250/ md	6000.00	6000.00
	Gap filling	2 mds	250/ md	250/ md	500.00	500.00
3	Plant protection measure					
	Chlorophyris, Malathion and Fungicide				918.00	1135.00
	Required manpower	3mds	250/ md	250/ md	750.00	750.00
4	Earthing up	35 mds	250/ md	250/ md	8,750.00	8,750.00
5	Manual weeding	20 mds	250/ md	250/ md	5000.00	5,000.00
6	Irrigation				2500.00	3000.00
7	Harvesting	110 mds	250/ md	250/ md	27500	27500
Total					92588	93588

ANNEXURE – IV (a)

TOTAL COST OF PRODUCTION UNDER DIFFERENT TREATMENTS (2017-18)

Treatments	Cost of Inputs treatment wise(/ha)									Application cost	Total Cost
	Fixed	N (Urea)	P(SSP)	K (MOP)	VC	GM	EC	F YM	BF		
M ₁ F ₁	80,4,08	3000	5280	1800						2500	92988
M ₁ F ₂	80,4,08	3000	5280	1800	10,000	2850			1500	3500	108338
M ₁ F ₃	80,4,08	3000	5280	1800		2850	18000			3500	114838
M ₁ F ₄	80,4,08	2250	3960	150	10000	2850		10000	1500	3500	114618
M ₁ F ₅	80,4,08	2250	3960	1350	-	2850	18000	10000		3500	122318
M ₂ F ₁	105158	3000	5280	1600						2500	117538
M ₂ F ₂	105158	3000	5280	1800	10,000	2850			1500	3500	133088
M ₂ F ₃	105158	3000	5280	1800		2850	18000			3500	139588
M ₂ F ₄	105158	2250	3960	1350	10000	2850		10000	1500	3500	140568
M ₂ F ₅	105158	2250	3960	1350	-	2850	18000	10000		3500	147068
M ₃ F ₁	93028	3000	5280	1800						2500	105168
M ₃ F ₂	93028	3000	5280	1800	10,000	2850			1500	3500	120518
M ₃ F ₃	93028	3000	5280	1800		2850	18000			3500	127018
M ₃ F ₄	93028	2250	3960	1350	10000	2850		10000	1500	3500	128438
M ₃ F ₅	93028	2250	3960	1350	-	2850	18000	10000		3500	134498

N.B: Price of Urea@ Rs 10/ kg, SSP: Rs 12/kg, MOP: Rs. 18/kg, VC: Rs 8/kg, EC: Rs 15/kg, BF: Rs75/kg Cowpea seed: Rs 90/kg, net selling price of jaggery: Rs32/kg

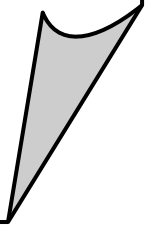
ANNEXURE – IV (b)

TOTAL COST OF PRODUCTION UNDER DIFFERENT TREATMENTS (2018-19)

Treatments	Cost of Inputs treatment wise(/ha)									Application cost	Total
	Fixed	N (Urea)	P(SSP)	K (MOP)	VC	GM	EC	F YM	BF		
M ₁ F ₁	81188	3000	5280	2200						2500	94168
M ₁ F ₂	81188	3000	5280	2200	10,000	2850			1500	3500	109518
M ₁ F ₃	81188	3000	5280	2200		2850	18000			3500	116018
M ₁ F ₄	81188	2250	3960	1650	10000	2850		10000	1500	3500	116898
M ₁ F ₅	81188	2250	3960	1650	-	2850	18000	10000		3500	123398
M ₂ F ₁	106089	3000	5280	2200						2500	119069
M ₂ F ₂	106089	3000	5280	2200	10,000	2850			1500	3500	134419
M ₂ F ₃	106089	3000	5280	2200		2850	18000			3500	140919
M ₂ F ₄	106089	2250	3960	1650	10000	2850		10000	1500	3500	141799
M ₂ F ₅	106089	2250	3960	1650	-	2850	18000	10000		3500	148299
M ₃ F ₁	93588	3000	5280	2200						2500	106568
M ₃ F ₂	93588	3000	5280	2200	10,000	2850			1500	3500	121918
M ₃ F ₃	93588	3000	5280	2200		2850	18000			3500	128418
M ₃ F ₄	93588	2250	3960	1650	10000	2850		10000	1500	3500	129298
M ₃ F ₅	93588	2250	3960	1650	-	2850	18000	10000		3500	135798

Price of Urea@ Rs 10/ kg, SSP: Rs 12/kg, MOP: Rs. 22/kg, VC: Rs 8/kg, EC: Rs 15/kg, BF: Rs75/kg Cowpea seed: Rs 90/kg, net selling price of jaggery: Rs32/kg

Appendices... 



APPENDIX – I

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on total no. of shoots

Source of variation	Total number of shoots												
	2017-18							2018-19					
	df	90 DAP	120 DAP	150 DAP	180 DAP	210 DAP	240 DAP	90 DAP	120 DAP	150 DAP	180 DAP	210 DAP	240 DAP
Replication	2	5.93	33.65	10.91	27.16	304.37	146.14	6.44	3.088	11.24	16.82	254.64	118.31
Crop establishment techniques (M)	2	13.26	1491.78*	2065.83*	1903.50*	1334.16*	1769.97*	29	1598.51*	2315.37*	1711.78*	1388*	2140.54*
Error a	4	58.85	45.48	102.06	186.64	47.45	77.93	60.40	41.52	66.99	95.13	79.71	83.86
INM(F)	4	12.31	55.87*	160.08*	477.27*	538.66*	201.10*	10.90*	70.23	161.06*	287.72*	460.35*	195.00*
M x F	8	0.73	6.37	1.044	52.71*	25.99*	28.95	2.08	24.35	0.83	28.80*	23.72*	16.22
Error b	24	6.96	9.36	9.40	22.41	14.65	14.30	4.91	10.40	7.63	8.06	9.96	15.80

*Significant at 5 % level of significance

APPENDIX – II

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on No. of shoots plant⁻¹

Source of variation	No of shoots								
	2017-18					2018-19			
	df	90 DAP	150 DAP	180 DAP	210 DAP	90 DAP	150 DAP	180 DAP	210 DAP
Replication	2	0.189	0.261	3.48	1.32	0.193	0.249	0.764	1.298
Crop establishment technique (M)	2	45.047*	227.04*	231.55*	182.78*	46.558*	221.09*	219.64*	183.123*
Error a	4	0.302	0.142	1.19	0.51	0.299	0.180	0.38	0.494
INM(F)	4	0.055	0.306*	1.48*	1.33*	0.0554	0.352*	1.25*	1.332*
M x F	8	0.017	0.0363	0.55*	0.66*	0.017	0.035	0.71*	0.662*
Error b	24	0.022	0.024	0.08	0.15	0.021	0.033	0.06	0.145

*Significant at 5 % level of significance

APPENDIX – III

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on number of physiologically active leaves plant⁻¹

Source of variation	2017-18							2018-19					
	d.f	120 DAP	150 DAP	180 DAP	210 DAP	240 DAP	270 DAP	120 DAP	150 DAP	180 DAP	210 DAP	240 DAP	270 DAP
Replication	2	0.108	0.072	0.249	2.26	36.78	0.52	0.158	0.326	0.033	1.63	30.98	0.088
Crop establishment technique (M)	2	0.027	0.228	5.843*	5.35*	10.64*	1.59*	0.030	0.152	2.62*	4.73*	6.48*	2.69*
Error a	4	0.199	0.242	0.572	0.630	0.77	0.20	0.22	0.350	0.344	0.664	0.842	0.38
INM(F)	4	0.092	0.069	1.123*	0.925*	1.51*	0.59*	0.084	0.077	0.852*	0.889*	1.54*	0.60*
M x F	8	0.047	0.024	0.162	0.076	0.27	0.07	0.046	0.026	0.166	0.083	0.31	0.08
Error b	24	0.044	0.052	0.080	0.093	0.23	0.10	0.037	0.061	0.091	0.137	0.29	0.20

*Significant at 5 % level of significance

APPENDIX – IV

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on plant height

Source of variation	Plant height (cm)								
	2017-18					2018-19			
	df	150DAP	210 DAP	270 DAP	330DAP	150DAP	210 DAP	270 DAP	330DAP
Replication	2	14.69	158.60	120.27	234.02	13.73	91.12	119.70	219.8
Crop establishment technique (M)	2	100.82*	446.34*	736.86*	2972.02*	133.68*	535.70*	1352.13*	2785.63*
Error a	4	7.98	63.23	86.98	393.39	6.13	70.67	90.22	264.17
INM(F)	4	44.66*	282.07*	547.59*	363.40*	18.33*	248.44*	393.00*	403.29*
M x F	8	2.18	15.47	43.93	256.44	1.88	9.08	26.54	261.50
Error b	24	1.24	8.64	21.69	111.98	1.13	9.08	19.24	113.08

*Significant at 5 % level of significance

APPENDIX – V (a)

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on leaf area shoot⁻¹

Source of variation	2017-18						
	df	150 DAP	180 DAP	210 DAP	240 DAP	330 DAP	390 DAP
Replication	2	3066.91	20429.30	1093382.69	4241.25	56131.88	35063.79
Crop establishment technique (M)	2	2922.25	164114.35*	1234515.43*	1017106.41*	192593.34	59374.01
Error a	4	2587.07	12995.27	110543.28	113518.70	61866.26	31033.31
INM(F)	4	2425.78*	18633.81*	77185.60*	178482.22*	82556.05*	2848.00
M x F	8	318.65	1942.31	15947.12	3823.68	7052.49	1774.51
Error b	24	296.51	1178.07	9121.33	11609.27	8500.09	3896.52

*Significant at 5 % level of significance

APPENDIX – V (b)

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on leaf area shoot⁻¹

Source of variation	2018-19						
	df	150 DAP	180 DAP	210 DAP	240 DAP	330 DAP	390 DAP
Replication	2	14964.79	166582.64	966260.80	57915.50	234986.20	34080.23
Crop establishment technique (M)	2	283.66	158886.81*	863401.45*	1533486.04*	342937.06	27639.43
Error a	4	3641.85	12765.11	110676.64	83395.17	168368.38	28786.15
INM (F)	4	1995.37*	36958.73*	115034.02*	83805.48*	175385.30*	3255.91
M x F	8	325.81	5347.32	16829.07	6614.57	3226.03	1339.02
Error b	24	423.25	2861.80	12112.14	8409.55	5542.83	3374.79

*Significant at 5 % level of significance

APPENDIX – VI

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on Leaf area index (LAI)

Source of variation	2017-18							2018-19					
	df	120 DAP	150 DAP	180 DAP	210 DAP	240 DAP	300 DAP	120 DAP	150 DAP	180 DAP	210 DAP	240 DAP	300 DAP
Replication	2	0.0221	0.026	0.827	1.25	1.336	0.952	0.0237	0.0281	0.497	0.80	0.37	1.165
Crop establishment technique (M)	2	0.0411*	0.158*	1.456*	4.30*	11.113*	1.812*	0.0467*	0.1688*	1.533*	4.85*	8.98*	2.166*
Error a	4	0.0056	0.007	0.053	0.26	0.482	0.245	0.0058	0.0032	0.045	0.24	0.49	0.231
INM(F)	4	0.0064	0.014	0.249	0.80	2.116	0.359	0.0052	0.0099	0.270	0.96	1.66	0.553
M x F	8	0.0004*	0.002*	0.029*	0.09*	0.122*	0.049*	0.0002*	0.0008*	0.018*	0.03*	0.07*	0.009*
Error b	24	0.0008	0.002	0.013	0.04	0.055	0.040	0.0005	0.0008	0.010	0.03	0.03	0.031

*Significant at 5 % level of significance

APPENDIX – VII

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on Leaf area duration (LAD)

Source of variation	LAD						
		90-150DAP		150-210DAP		210-270 DAP	
	df	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Replication	2	4.46	6.71	2373.08	1058.87	2878.40	2560.56
Crop establishment technique (M)	2	49.80*	110.31*	8399.66*	5852.14*	7971.93*	14603.95*
Error a	4	6.55	7.64	382.20	244.24	801.13	691.22
INM(F)	4	6.86*	7.78*	1979.08*	826.40*	4177.73*	3913.62*
M x F	8	0.46	1.56	157.25*	93.22*	301.79*	538.32*
Error b	24	1.00	0.79	75.71	18.33	35.13	7.51

*Significant at 5 % level of significance

APPENDIX – VIII

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on Crop growth rate (CGR)

Source of variation	Crop Growth Rate										
	90-150DAP		150-210 DAP		210 -270 DAP		270-330DAP		330-390DAP		
	df	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Replication	2	0.020	0.022	0.59	2.35	12.47	14.90	58.43	24.51	3.425	0.350
Crop establishment technique (M)	2	0.460	0.553	17.81*	15.49*	72.93*	58.29*	60.57*	61.45*	1.830	2.082
Error a	4	0.183	0.203	1.85	2.18	8.43	6.68	7.96	6.42	0.743	0.888
INM(F)	4	0.207	0.145	7.24*	7.54*	21.13*	21.33*	22.26*	28.83*	0.217	0.225
M x F	8	0.049	0.044	0.08	0.24	2.26	1.79	0.13	0.50	0.021	0.089
Error b	24	0.078	0.06	0.16	0.15	1.01	1.12	1.16	0.66	0.081	0.088

*Significant at 5 % level of significance

APPENDIX – IX

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on Relative growth rate (RGR)

Source of variation	Relative Growth Rate (RGR)								
	90-150DAP			150-210 DAP		210 -270 DAP		270-330DAP	
	df	2018	2019	2018	2019	2018	2019	2018	2019
Replication	2	0.598	0.305	0.282	3.140	5.753	4.408	2.709	3.295
Crop establishment technique (M)	2	0.522	0.254	0.988	1.348	0.857	0.588	0.705	0.711
Error a	4	0.273	0.282	0.363	0.750	0.142	0.269	0.578	0.774
INM(F)	4	0.129	0.106	0.512	0.463	0.431	0.511	0.233	0.239
M x F	8	0.026	0.023	0.049	0.038	0.112	0.098	0.023	0.022
Error b	24	0.026	0.025	0.069	0.057	0.064	0.074	0.050	0.061

*Significant at 5 % level of significance

APPENDIX – X

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on N related parameters

Source of variation	Chlorophyll content (mgg ⁻¹) at 330 DAP			Chlorophyll content (mgg ⁻¹) at 360 DAP		Green seeker NDVI		Crop canopy temperature (°C)	
	df	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Replication	2	0.011	0.049	0.011	0.026	0.0013	0.0025	3.15	1.99
Crop establishment technique (M)	2	0.007	0.005	0.054	0.031	0.0013	0.0030	3.58	7.32
Error a	4	0.023	0.030	0.046	0.055	0.0025	0.0006	8.04	7.24
INM(F)	4	0.046*	0.048*	0.068*	0.077*	0.0028*	0.0026*	5.46*	4.87*
M x F	8	0.003	0.006	0.002	0.002	0.0007	0.0003	0.99	0.60
Error b	24	0.007	0.007	0.005	0.007	0.0003	0.0004	0.90	1.12

*Significant at 5 % level of significance

APPENDIX – XI

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on root length and root dry weight

Source of variation	Root length (cm)							Root dry weight					
	120DAP			150DAP		180DAP		120DAP		150DAP		180DAP	
	df	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Replication	2	19.41	22.04	11.26	25.99	38.26	41.59	0.40	9.42	14.98	16.71	11.04	45.33
Crop establishment technique (M)	2	193.56*	147.48*	214.34*	184.47*	167.19*	279.57*	551.94*	522.71*	683.62*	659.02*	1497.24*	1131.77*
Error a	4	2.25	2.31	4.25	2.71	3.43	6.23	4.47	7.55	16.91	16.11	12.43	10.72
INM(F)	4	9.75*	6.57*	5.94*	9.06*	40.13*	53.10*	15.68*	18.25*	30.34*	30.14*	41.40*	21.62*
M x F	8	1.25	0.47	0.43	0.22	0.63	2.81	0.79	0.61	2.69	1.95	3.67	3.182
Error b	24	0.74	0.61	1.17	0.31	1.65	1.9	0.83	0.43	1.33	1.05	1.67	1.82

*Significant at 5 % level of significance

APPENDIX – XII

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on dry weight of above ground biomass

Source of variation	Dry weight of above ground biomass												
	2017-18							2018-19					
		210 DAP			270 DAP			210 DAP			270 DAP		
	df	Stem	Leaves	Total	stem	Leaves	Total	Stem	leaves	Total	Stem	leaves	Total
Replication	2	3.21	76.02	140.83	202.16	86.82	200.25	9.13	89.45	151.31	154.63	43.06	259.15
Crop establishment technique (M)	2	319.87*	39.24	779.38*	149.03*	158.39	2058.062*	235.74*	80.80	576.71*	1461.16*	132.05	2413.39*
Error a	4	7.86	24.62	70.27	19.03	58.82	151.03	6.88	36.99	54.42	58.39	72.55	271.60
INM(F)	4	53.09*	64.05*	124.43*	74.92*	86.68*	214.78*	37.37*	46.53*	124.31*	658.68*	55.68*	1002.05*
M x F	8	1.23	13.16	10.84	4.28	5.45	4.48	1.33	2.33	10.46	7.27	2.64	63.38
Error b	24	0.90	8.11	7.87	6.58	8.53	16.97	0.759	3.49	6.86	11.58	7.66	30.79

*Significant at 5 % level of significance

APPENDIX – XIII

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on yield attributing characters

Source of variation	Millable cane length			Millable cane diameter (cm)		Number of millable cane ('000 ha ⁻¹)		Single cane weight	
	df	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Replication	2	68.88	358.49	0.003	0.077	128.96	547.85	0.0013	0.0024
Crop establishment technique (M)	2	2123.80*	3710.14*	0.002	0.005	489.28*	494.50*	0.0219*	0.0242*
Error a	4	296.52	412.66	0.033	0.02	51.97	43.59	0.0024	0.0030
INM(F)	4	665.64*	828.19*	0.008	0.005	109.13*	89.66*	0.0057*	0.0073*
M x F	8	43.89	152.74	0.001	0.002	21.182	2.10	0.0008	0.0007
Error b	24	53.48	69.41	0.004	0.002	11.95	7.75	0.0013	0.0012

*Significant at 5 % level of significance

APPENDIX – XIV

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on yield attributing characters

Source of variation	d.f	Length of internodes						Number of internodes plant ⁻¹	
		Bottom		Middle		Top		2017-18	2018-19
		2017-18	2018-19	2017-18	2018-19	2017-18	2018-19		
Replication	2	0.60	0.30	2.55	0.47	0.06	0.08	18.85	5.33
Crop establishment technique (M)	2	3.85*	4.48*	8.82*	14.40*	3.94*	3.10*	12.15*	20.96*
Error a	4	0.50	0.56	1.22	1.17	0.45	0.42	1.69	3.01
INM(F)	4	0.55*	0.62*	1.24*	1.17*	1.33*	0.64*	6.00*	5.59*
M x F	8	0.46	0.41	0.13	0.23	0.38	0.08	1.82	2.43
Error b	24	0.20	0.22	0.19	0.23	0.21	0.11	0.91	1.08

*Significant at 5 % level of significance

APPENDIX – XV

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on yield of sugarcane and Harvest index (HI)

Source of variation	Cane yield			Green top			Trash yield			Biological yield		Harvest index		
	df	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	2017-18	2018-19
Replication	2	212.55	221.42	205.34	2.96	3.12	2.14	1.31	0.52	1.45	50.64	19.77	24.33	22.88
Crop establishment technique (M)	2	1644.51*	1531.91*	1584.94*	7.13*	9.48*	8.47*	6.034*	4.74*	5.96*	2187.66*	2016.24*	7.92	7.21
Error a	4	130.45	62.81	89.07	0.92	0.85	0.77	0.27	0.29	0.47	70.13	188.72	21.14	22.00
INM(F)	4	232.57*	216.04*	224.00*	6.71*	3.19*	4.36*	0.45*	0.99*	0.65*	305.22*	281.93*	1.82	0.10
M x F	8	6.38	21.18	8.07	1.018	0.04	0.31	0.050	0.035	0.027	36.35	10.24	4.34	4.15
Error b	24	13.53	10.46	8.79	0.45	0.36	0.28	0.03	0.048	0.076	17.60	17.14	4.61	2.98

*Significant at 5 % level of significance

APPENDIX – XVI

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on juice quality parameters (Field brix)

Source of variation	Field brix at 360 DAP							Field Brix at 420DAP					
	Bottom			Middle		Top		Bottom		Middle		Top	
	df	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Replication	2	1.92	20.61	8.52	5.06	0.38	0.51	3.72	0.98	7.79	10.51	1.78	0.91
Crop establishment technique (M)	2	0.20	1.105	1.87	2.13	0.50	0.42	0.08	0.10	0.47	0.14	1.65	0.75
Error a	4	3.88	1.96	1.90	1.72	1.56	0.82	2.79	5.94	1.85	2.42	3.76	2.97
INM(F)	4	0.52	0.37	0.36	0.37	0.18	0.12	0.52	0.39	0.54	0.20	0.20	0.23
M x F	8	0.11	1.03	0.84	0.13	0.74	0.60	0.11	0.28	0.23	0.20	0.41	0.45
Error b	24	0.45	0.51	0.75	0.21	0.34	0.26	0.53	0.46	0.35	0.17	0.37	0.32

APPENDIX – XVII

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on juice quality parameters and CCS yield

Source of variation	Juice recovery%			Sucrose%		Purity (%)		CCS%		CCS yield (tha ⁻¹)	
	df	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Replication	2	57.88	61.46	3.62	3.79	17.62	21.26	0.40	2.07	1.77	1.18
Crop establishment technique (M)	2	20.71	29.93	0.56	0.84	10.08	1.89	0.37	1.12	24.53*	42.95*
Error a	4	9.98	13.40	1.40	0.97	14.34	19.15	0.38	0.39	1.21	1.76
INM(F)	4	32.29*	50.25*	0.23	0.27	5.94	8.81	0.63*	0.61*	4.52*	2.87*
M x F	8	1.56	1.79	0.068	0.20	7.45	2.38	0.23	0.18	0.09	0.47
Error b	24	2.03	2.38	0.14	0.13	5.07	4.79	0.21	0.31	0.21	0.26

*Significant at 5 % level of significance

APPENDIX – XVIII

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on jaggery recovery and jaggery yield

Source of variation	df	Jaggery %		Jaggery yield	
		2018	2019	2018	2019
Replication	2	5.89	2.39	3.72	10.40
Crop establishment technique (M)	2	0.63	0.39	19.64*	19.48*
Error a	4	0.51	0.28	0.71	0.63
INM(F)	4	0.68*	0.83*	5.05*	3.92*
M x F	8	0.065	0.089	0.16	0.17
Error b	24	0.13	0.08	0.12	0.17

*Significant at 5 % level of significance

APPENDIX – XIX

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on nitrogen content and uptake

Source of variation	N Content in different plant parts							N uptake by different plant parts					
	Green top		Cane stalk		trash		Green top		Cane stalk		trash		
	df	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Replication	2	0.0088	0.0084	0.0101	0.0016	0.0034	0.0041	51.92	64.18	571.53	903.42	46.17	112.06
Crop establishment technique (M)	2	0.0048	0.0046	0.0011	0.0004	0.0005	0.0016	113.56*	84.42*	4981.75*	5090.48*	231.96*	181.36*
Error a	4	0.0043	0.0041	0.0044	0.0011	0.0011	0.0013	5.77	7.15	159.41	121.06	21.79	16.40
INM(F)	4	0.0031*	0.0029*	0.0016*	0.0015*	0.0010*	0.0014*	63.70*	39.95*	806.36*	661.14*	25.39*	92.01*
M x F	8	0.0002	0.0002	0.0003	0.0002	0.0001	0.0001	3.74	2.69	46.55	45.16	3.41	1.32
Error b	24	0.0005	0.0004	0.0004	0.0003	0.0002	0.0002	2.10	2.28	39.69	23.17	1.63	2.23

APPENDIX – XX

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on phosphorous content and uptake

Source of variation	P content in different plant parts							P uptake by different plant parts					
	Green top			Cane stalk		trash		Green top		Cane stalk		trash	
	df	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Replication	2	0.00003	0.00008	0.00009	0.00019	0.00007	0.00004	7.14	5.38	73.72	71.55	0.18	0.14
Crop establishment technique (M)	2	0.00005	0.00004	0.00004	0.00001	0.000008	0.000006	1.26*	1.16*	140.81*	109.85*	7.37*	5.52*
Error a	4	0.00007	0.000002	0.00002	0.00009	0.00007	0.00003	0.17	0.16	14.23	15.58	0.64	0.62
INM(F)	4	0.00003	0.00001	0.00001	0.000007	0.00001	0.00001	0.54*	0.33*	28.53*	21.09*	1.60*	1.68*
M x F	8	0.00002	0.000002	0.000002	0.000003	0.000002	0.000003	0.01	0.02	2.43	1.64	0.31	0.35
Error b	24	0.00001	0.000005	0.000005	0.00001	0.00001	0.000005	0.03	0.06	2.00	2.92	0.21	0.18

*Significant at 5 % level of significance

APPENDIX – XXI

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on potassium content and uptake

Source of variation	K content in different plant parts						K uptake by different plant parts						
	Green top		Cane stalk		trash		Green top		Cane stalk		trash		
	df	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Replication	2	0.0680	0.008	0.0022	0.0050	0.0060	0.0061	119.06	10.42	1620.58	1110.67	2.53	27.15
Crop establishment technique (M)	2	0.0085	0.019	0.0002	0.0008	0.0005	0.0005	122.31*	112.54*	7172.28*	4644.02*	107.69*	70.99*
Error a	4	0.0051	0.014	0.0006	0.0034	0.0022	0.0023	16.88	15.79	280.57	291.86	10.47	8.18
INM(F)	4	0.0025	0.0019	0.0041*	0.0021*	0.0006	0.0004	59.83*	26.68*	707.96*	751.06*	28.07*	22.44*
M x F	8	0.0008	0.0002	0.0003	0.0001	0.0003	0.0003	7.85	0.95	63.55	12.98	2.30	2.24
Error b	24	0.0013	0.0009	0.0001	0.0002	0.0002	0.0002	3.58	4.44	51.02	43.37	1.33	1.9

*Significant at 5 % level of significance

APPENDIX – XXII

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on total nutrient uptake by plant

Source of variation	df	Total Nitrogen uptake (Kg/ha)		Total Phosphorous uptake (Kg/ha)		Total Potassium uptake (Kg/ha)	
		2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Replication	2	1724.72	2854.12	80.89	120.53	564.74	806.38
Crop establishment technique (M)	2	9206.81*	8526.72*	219.59*	212.52*	8830.21*	6952.06*
Error a	4	891.68	912.49	17.77	14.60	360.59	503.95
INM(F)	4	1881.15*	2287.18*	42.01*	31.03*	2376.21*	2689.13*
M x F	8	49.37	55.54	4.51	1.31	48.61	43.01
Error b	24	47.02	59.74	2.31	1.70	31.09	35.10

*Significant at 5 % level of significance

APPENDIX – XXIII

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on Soil pH, Soil organic carbon % and microbial population

Source of variation	df	Soil pH		Soil organic carbon %		Fungi population		Bacterial population	
		2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Replication	2	0.064	0.028	0.0017	0.0011	0.160	0.898	0.33	0.35
Crop establishment technique (M)	2	0.002	0.005	0.0006	0.0004	0.004	0.025	0.0008	0.005
Error a	4	0.057	0.071	0.0018	0.0023	0.103	0.119	0.15	0.15
INM (F)	4	0.005	0.008	0.0152*	0.0204*	0.990*	0.713*	4.04*	4.11*
M x F	8	0.002	0.011	0.0001	0.0001	0.008	0.008	0.015	0.026
Error b	24	0.002	0.008	0.0003	0.0002	0.026	0.039	0.036	0.045

*Significant at 5 % level of significance

APPENDIX – XXIV

Analysis of variance (Mean square) for the effect of crop establishment techniques (M) and integrated nutrient management (INM) on soil nutrient status

Source of variation	Available N in soil			Available P ₂ O ₅ in soil		Available K ₂ O in soil	
	df	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Replication	2	678.31	4759.13	18.72	13.30	383.86	302.63
Crop establishment technique (M)	2	33.0	1.33	2.147	0.49	60.38	90.16
Error a	4	283.79	444.52	4.21	5.21	387.86	244.94
INM (F)	4	920.72*	1001.37*	28.31*	23.30*	814.35*	665.52*
M x F	8	88.03	20.88	0.90	1.11	107.02	79.74
Error b	24	38.25	47.89	0.64	0.93	46.38	58.14

*Significant at 5 % level of significance