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RESEARCH PAPER

Integrated nutrient management in popcorn

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Abstract: A field experiment was conducted at the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad to study the integrated nutrient management in popcorn (*Zea mays* var. *everata*) during *kharif* 2018. The experiment was laid out in split -plot design with three replications consisting of four organic levels as main plot (O_1: FYM @ 5 t ha^{-1}, O_2: FYM @ 7.5 t ha^{-1}, O_3 : VC @ 1.25 t ha^{-1} and O_4 : VC @ 2.5 t ha^{-1}) and three fertilizer levels as sub plot (F_1: 75 % RDF, F_2: 100 % RDF and F_3: 125 % RDF) along with one absolute control. The experimental results revealed that, application of VC @ 2.5 t ha^{-1} recorded significantly higher total dry matter accumulation (205.91 g plant^{-1}) at harvest, grain yield (3,541kg ha^{-1})and net returns (₹ 76,911 ha^{-1}) and found at par with application of FYM @ 7.5 t ha^{-1} (205.91 g plant^{-1}, 3,494 kg ha^{-1} and ₹ 75, 845 ha^{-1}, respectively) compared to other organic levels. Among fertilizer levels, application of 125 % RDF recorded significantly higher total dry matter accumulation (207.20 g plant^{-1}) at harvest, grain yield (3,619 kg ha^{-1}) and net returns (₹ 80,989 ha^{-1}) over other levels. Interaction effect indicated that application of VC @ 2.5 t ha^{-1} + 125 % RDF recorded significantly higher total dry matter accumulation (219.20 g plant^{-1}) at harvest, grain yield (4,003 kg ha^{-1}) and net returns (₹ 91,824 ha^{-1}) and found at par with application of FYM @ 7.5 t ha^{-1} + 125 % RDF (216.63 g plant^{-1}, 3,983 kg ha^{-1} and ₹ 91,676 ha^{-1}, respectively). Absolute control recorded significantly lowest total dry matter accumulation (₹ 144 g plant^{-1}), grain yield (₹ 1,378 kg ha^{-1}) and net returns (₹ 21,437 ha^{-1}) compared to rest of the treatment combinations.

Key words: Fertilizer, Nutrient, Organics, Popcorn, Vermicompost

Introduction

Maize (*Zea mays* L.) is one of the important cereal crops stands first with respect to production in the world. In India, it ranks third after rice and wheat. Maize is known as "Queen of cereals" because of its high production potential and wider adaptability. It is not only represents a source of food, fodder and feed, but also gives rise to a range of by-products including glucose, starch and corn oil. Popcorn is a speciality type of corn grown in small acreage around urban areas. The ability to pop is the unique characteristic that distinguishes from other types of corn. Popcorn has more of hard endosperm and starch granules are so embedded in tough elastic colloidal material that confines and restricts to steam pressure generated within the granule on heating until it reaches explosive force (Weatherwax, 1922). The pops are a ready to eat products that could be used as snacks, break fast cereals, adjuncts in brewing. Popping improves the nutritional quality by reducing the antinutritional factors, increased protein, carbohydrates digestibility and provides dietary fibre in soluble form. The demand for the popcorn products is increasing among the urban population. Out of total production of maize, 25 per cent of maize is consumed as a staple food in various forms including popcorn. In Karnataka, it is grown an area of about 15,000 hectare concentrated around urban areas such as Bangalore, Kolar, Chikkaballapur, Tumkur, Davangere and Belgaum due to better market outlet (Kanannavar, 2013).

There are several factors which are responsible for poor growth and yield of popcorncrop. One of the factor which is responsible for poor yield of crop is low fertility status of soils. At present, the only use of inorganic and organic fertilizer sources are also one of the main reasons for slow growth and low yield of maize. The organic sources maintain good soil aeration by improving soil structure and provide nutritious food to plant without any chemical residue. But organic manures are slow releasing, costly and reduce the overall yield of crop. The inorganic fertilizer are cheap, early releasing and require in very small amount as compare to organic fertilizer sources. But they degrade the soil, cause environmental and water pollution and serious health hazards in humans. Well decomposed farm yard manure (FYM) in addition to supplying plant nutrients also acts as binding material and improves the soil physical, chemical and biological properties. Vermicompost (VC) is rich in humus forming microbes and nitrogen fixers and drying of the VC does not deteriorate the microbial population. In recent years, the potential of FYM and VC to supply nutrients and enhance beneficial microbes for faster decomposition is being recognized widely both in field crops and horticultural crops. Thus, to maintain sustained higher productivity levels of crops and sustaining soil health, integrated plant nutrient management system (IPNMS) has become important. The basic concept of IPNMS is the promotion and maintenance of soil fertility for sustaining crop productivity through optimizing all possible organic, inorganic and biological sources in an integrated manner, appropriate to each farming situation in its ecological, soil and economic possibilities. The principle aim of IPNMS is efficient and judicious use of all the major sources of plant nutrients in an integrated manner, so as to get maximum economic yield without any deleterious effect on physico-chemical and biological properties of the soil.

Material and methods

A field experiment was conducted during *kharif* 2018 at the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad. Soil is medium deep black with neutral pH and medium in organic carbon with available nitrogen, phosphorus and potassium content 277, 35.22 and 366.55 kg ha^{-1}, respectively. American seed is a variety of popcorn and crop was sown by opening furrow using marker with a spacing of 60 × 20 cm. Seeds were treated with *Azosprillium* and PSB @ 20 g kg^{-1} of seeds is common for all the treatments expect absolute control. The crop was sown on 28th June 2018 and followed by gap filling, thinning and harvesting at 12th October 2018. The experiment was laid out in split -plot design with three replications consisting of four organic levels as main plot (O_1: Farm yard manure (FYM) @ 5 t ha^{-1}, O_2: FYM @ 7.5 t ha^{-1}, O_3: Vermicompost (VC) @ 1.25 t ha^{-1} and O_4:VC @ 2.5 t ha^{-1}) and three fertilizer levels as sub plot (F_1: 75 % RDF (recommended dose of fertilizer), F_2: 100 % RDF and F_3: 125 % RDF) with one absolute control outside the design. RDF for popcorn is 125: 75: 37.5 kg N: P_2O_5: K_2O ha^{-1} and $FeSO_4$ and $ZnSO_4$ @ 10 kg ha^{-1} is common for all the treatments expect absolute control. The inorganic fertilizers were applied in the form of urea, diammonium phosphate and muriate of potash. The entire quantity of phosphorus, potash and 50 per cent of nitrogen (N) were applied at the time of sowing and remaining 50 per cent N applied at 30 DAS as top dressing. The calculated quantity of FYM was incorporated 15 days prior to sowing and VC was incorporated at the time of sowing as per treatments. The nitrogen content of FYM and VC was 0.4 and 1.2 per cent, respectively. Insect and diseases were managed as per zonal package of practice for Karnataka (Zone 8).

The biometric characters like plant height, number of leaves, leaf area, leaf area index, leaf area duration (LAD), total dry matter accumulation (TDMA), absolute growth rate (AGR), crop growth rate (CGR)were calculated for different plant growth stages. The formulae given by Sticker *et al*. (1961) for leaf area, Watson (1952) for LAI, Radford (1967) for AGR and Watson (1956) for CGR were used for calculation.

Popping was done by using Carnival king popcorn popper machine. Popping per centage (%) was calculated by using the formula given by Singh and Srivastava (1993).

$$\text{Popping percentage} = \frac{\text{Number of popped kernels}}{\text{Total number of kernels}} \times 100$$

The expansion volume of pop (ml g^{-1})was estimated by rapeseed displacement method (Singh and Srivastava, 1993).

$$\text{Expansion volume of pop} = \frac{\text{Total popped volume (ml)}}{\text{Original weight of kernel (g)}} \times 100$$

Flake size (ml) was computed by using formula given by Singh and Srivastava (1993).

$$\text{Flake size} = \frac{\text{Total popped volume (ml)}}{\text{Number of popped kernels}} \times 100$$

Plant samples collected at harvesting stage to study the total dry matter accumulation were used to estimate nutrient uptake by the crop. The nitrogen, phosphorous, potassium uptake by the crop was analgised by modified kjeldhal method (Tandon,1998), Vanadomolybdate yellow colour method and Flame photometer method (Tandon,1998), respectively. Available soil nitrogen was estimated by modified alkaline permanganate oxidation method as described by Sahrawat and Burford (1982). Available phosphorus was determined by Olsen's methods as outlined by Sparks (1996) using Spectrophotometer (660 nm wavelength). Available potassium was extracted with neutral normal ammonium acetate. The potassium content in the solution was estimated by Flame photometer (Sparks, 1996).

Interpretation of the data was carried out in accordance with Gomez and Gomez (1984). The level of significance used in the 'F' and 't' test was p=0.05. The critical difference values were calculated wherever the 'F' test values were significant. The treatment means were compared by applying Duncan's Multiple Range Test (DMRT).

Result and discussion

Effect of organic levels

The grain and stover yield of popcorn were significantly influenced by organics are presented in Table No. 2. Application of VC @ 2.5 t ha^{-1} recorded significantly higher grain and stover yield (3,541 kg ha^{-1} and 69.8 q ha^{-1}, respectively) and found at par with application of FYM @ 7.5 t ha^{-1} (3,494 kg ha^{-1} and 69.8 q ha^{-1}, respectively). Application of VC @ 2.5 t ha^{-1} recorded 1.3, 20.0 and 23.0 % increase in grain yield over the application of FYM @ 7.5 t ha^{-1}, FYM @ 5 t ha^{-1} and VC @ 1.25 t ha^{-1}. The increased grain and stover yield was due to higher yield attributing characters presented in the table No.2 *viz.*, number of grains cob^{-1} (554.76), cob length (14.79 cm), cob girth (10.23 cm) and 1000 seed weight (150.33 g). Increase in the grain yield and yield attributes was mainly due to higher growth parameters are presented in the Table 1 (a) and Table 1 (b). Growth in terms of plant height (32.7, 165.2 and 175.7 cm), number of leaves (5.17, 12.89 and 7.47), leaf area per plant (26.21, 68.41 and 39.18 dm^2 $plant^{-1}$), LAI (2.18, 5.70 and 3.27) at 40, 80 DAS and at harvest, LAD (157.70 and 179.32 days) at 40 to 80 DAS and 80 to harvest. The higher total dry matter accumulation (TDMA) per plant (at 40, 80 DAS and at harvest were 24.06, 158.16 and 205.91 g, respectively) resulted in higher AGR and CGR (3.35 g day^{-1} and 27.93 g m^{-2} day^{-1}) at 40 to 80 DAS. Increased growth parameters might be attributed to increased nitrogen, phosphorous and potassium uptake at harvest (189, 34.29 and 158.90 kg ha^{-1}, respectively) as evidenced by increased available soil nitrogen, phosphorous and potassium (242.51, 35.42 and 281.94 kg ha^{-1}, respectively). These results were in agreement with findings of Prasad *et al.* (2018) in maize also revealed that vermicompost is having higher nutrient content, faster decomposition rate, quick release of nutrients and enhancing the microbial population. FYM encourage the biological activity, release of organic acids that might have mobilized the fixed soil nutrients to available form and release of nutrients

Table 1 (a). Growth parameters of popcorn as influenced by organic manures and fertilizer levels

Treatments	Plant height (cm)			Number of leaves			LA (dm^2 $plant^{-1}$)			LAI		
	40 DAS	80 DAS	Harvest-	40 DAS	80 DAS	Harvest	40 DAS	80 DAS	Harvest	40 DAS	80 DAS	Harvest
Organic levels (O)												
$O_{1:}$ FYM @ 5 t ha^{-1}	28.6^{b}	153.0^{b}	160.0^{c}	4.84^{ab}	11.78^{b}	6.76^{b}	19.77^{b}	54.14^{b}	31.08^{b}	1.65^{b}	4.51^{b}	2.59^{b}
$O_{2:}$ FYM @ 7.5 t ha^{-1}	31.9^{a}	161.1^{a}	170.8^{b}	5.04^{a}	12.87^{a}	7.43^{a}	26.03^{a}	66.33^{a}	38.36^{a}	2.17^{a}	5.53^{a}	3.20^{a}
$O_{3:}$ Vermicompost @ 1.25 t ha^{-1}	28.3^{b}	142.3^{b}	154.0^{c}	4.60^{b}	11.62^{b}	6.44^{b}	17.73^{b}	53.62^{b}	29.76^{b}	1.48^{b}	4.47^{b}	2.48^{b}
$O_{4:}$ Vermicompost @ 2.5 t ha^{-1}	32.7^{a}	165.2^{a}	175.7^{a}	5.17^{a}	12.89^{a}	7.47^{a}	26.21^{a}	68.41^{a}	39.18^{as}	2.18^{a}	5.70^{a}	3.27^{a}
S.Em. ±	1.0	3.3	1.3	0.09	0.21	0.09	1.09	1.79	1.18	0.09	0.14	0.09
Fertilizers levels (F)												
$F_{1:}$ 75 % RDF	27.7^{c}	147.1^{c}	155.7^{c}	4.66^{c}	11.62^{c}	6.56^{c}	17.96^{c}	53.81^{c}	30.25^{c}	1.50^{c}	4.48^{c}	2.52^{c}
$F_{2:}$ 100 % RDF	30.6^{b}	152.2^{b}	163.5^{b}	4.90^{b}	12.25^{b}	7.05^{b}	22.85^{b}	60.69^{b}	34.99^{b}	1.90^{b}	5.06^{b}	2.92^{b}
F_3: 125 % RDF	32.9^{a}	166.9^{a}	176.2^{a}	5.18^{a}	13.00^{a}	7.47^{a}	26.50^{a}	67.37^{a}	38.55^{a}	2.21^{a}	5.61^{a}	3.21^{a}
S.Em. ±	0.5	1.5	0.4	0.07	0.19	0.10	0.80	1.62	0.94	0.06	0.13	0.07
Interaction (O × F)												
$O_1F_{1:}$ FYM @ 5 t ha^{-1}+75 % RDF	25.5^{e}	146.8^{cd}	152.5^{e}	4.67^{c-d}	11.07^{cd}	6.27^{ef}	15.03^{ef}	47.40^{e}	26.85^{f}	1.25^{ef}	3.95^{e}	2.24^{f}
$O_1F_{2:}$ FYM @ 5 t ha^{-1}+100 % RDF	28.6^{de}	152.1^{bc}	160.7^{d}	4.80^{b-d}	11.87^{bc}	6.73^{c-e}	19.64^{c-e}	54.56^{c-e}	30.96^{d-f}	1.64^{c-e}	4.55^{c-e}	2.58^{d-f}
O1F_3: FYM @ 5 t ha^{-1}+125 % RDF	31.8^{a-d}	160.2^{b}	166.9^{c}	5.07^{b-d}	12.40^{ab}	7.27^{a-c}	24.64^{bc}	60.45^{bc}	35.42^{b-d}	2.05^{a-c}	5.04^{bc}	2.95^{b-d}
$O_2F_{1:}$ FYM @ 7.5 t ha^{-1} + 75 % RDF	29.6^{cd}	147.9^{cd}	157.5^{c}	4.80^{b-d}	12.40^{ab}	7.10^{b-d}	21.42^{cd}	58.61^{b-d}	33.64^{c-e}	1.79^{cd}	4.88^{b-d}	2.80^{c-e}
$O_2F_{2:}$ FYM @ 7.5 t ha^{-1} + 100 % RDF	32.3^{a-c}	156.0^{bc}	166.7^{b}	5.07^{b-d}	12.67^{ab}	7.53^{ab}	26.93^{ab}	66.48^{ab}	39.45^{a-c}	2.24^{ab}	5.54^{ab}	3.29^{a-c}
$O_2F_{3:}$ FYM @ 7.5 t ha^{-1} + 125 % RDF	33.9^{ab}	179.3^{a}	188.3^{a}	5.27^{ab}	13.52^{a}	7.67^{ab}	29.67^{a}	73.90^{a}	41.99^{a}	2.48^{a}	6.16^{a}	3.50^{a}
$O_3F_{1:}$ VC @ 1.25 t ha^{-1} + 75 % RDF	25.2^{e}	138.5^{d}	146.4^{e}	4.33^{e}	10.60^{d}	5.87^{f}	13.86^{f}	48.19^{de}	26.72^{f}	1.16^{f}	4.02^{de}	2.23^{f}
$O_3F_{2:}$ VC @ 1.25 t ha^{-1} + 100 % RDF	28.5^{de}	140.7^{d}	154.2^{d}	4.60^{de}	11.73^{b-d}	6.47^{d-f}	17.38^{d-f}	52.43^{c-e}	28.96^{ef}	1.45^{d-f}	4.37^{c-e}	2.41^{ef}
O_3F_3: VC @ 1.25 t ha^{-1} + 125 % RDF	31.1^{b-d}	147.7^{cd}	$161.5b^{c}$	4.87^{b-d}	12.53^{ab}	7.00^{b-d}	21.95^{cd}	60.24^{bc}	33.60^{c-e}	1.83^{b-d}	5.02^{bc}	2.80^{c-e}
$O_4F_{1:}$ VC @ 2.5 t ha^{-1} + 75 % RDF	30.4^{b-d}	155.2^{bc}	166.6^{c}	4.83^{b-d}	12.40^{ab}	7.00^{b-d}	21.53^{cd}	61.04^{bc}	33.79^{c-e}	1.79^{cd}	5.09^{bc}	2.82^{c-e}
$O_4F_{2:}$ VC @ 2.5 t ha^{-1} + 100 % RDF	32.9^{a-c}	160.1^{b}	172.6^{b}	5.13^{a-c}	12.73^{ab}	7.47^{ab}	27.44^{ab}	69.31^{ab}	40.58^{ab}	2.29^{a}	5.78^{ab}	3.38^{ab}
$O_4F_{3:}$ VC @ 2.5 t ha^{-1} + 125 % RDF	35.0^{a}	180.5^{a}	188.4^{a}	5.53^{a}	13.53^{a}	7.93^{a}	29.75^{a}	74.88^{a}	43.18^{a}	2.49^{a}	6.24^{a}	3.60^{a}
S.Em.±	1.3	4.1	1.5	0.15	0.37	0.20	1.71	3.20	1.94	0.14	0.26	0.16
Absolute control (C)	18.8^{f}	106.0^{e}	113.4^{f}	3.67^{f}	7.80^{e}	6.07^{g}	8.67^{g}	25.00^{g}	17.84^{g}	0.72^{g}	2.08^{f}	1.49^{g}
S.Em.±	1.3	3.8	2.1	0.23	0.38	0.24	1.66	3.15	1.97	0.13	0.26	0.16

DAS: Days after sowing, RDF: Recommended dose of fertilizer , 100 % RDF: 125: 75: 37.5 kg N: P_2O_5: K_2O ha^{-1}

Table 1 (b). Growth parameters of popcorn as influenced by organic manures and fertilizer levels

Treatments	LAD (days)		TDMA (g plant^{-1})			AGR (g day^{-1})		CGR (g m^{-2}day^{-1})	
	40-80 DAS	80 DAS-Harvest	40 DAS	80 DAS	Harvest	40 - 80 DAS	80 - Harvest	40 - 80 DAS	80 - Harvest
Organic levels (O)									
$O_{1:}$ FYM @ 5 t ha^{-1}	123.18^{b}	142.02^{b}	19.97^{b}	141.58^{b}	186.73^{b}	3.04^{b}	1.51^{a}	25.32^{b}	12.54^{a}
$O_{2:}$ FYM @ 7.5 t ha^{-1}	153.93^{a}	174.48^{a}	24.00^{a}	156.48^{a}	203.82^{a}	3.31^{a}	1.58^{a}	27.59^{a}	13.15^{a}
$O_{3:}$ Vermicompost @ 1.25 t ha^{-1}	118.92^{b}	138.96^{b}	19.40^{b}	138.98^{b}	183.90^{b}	2.99^{b}	1.50^{a}	24.90^{b}	12.47^{a}
$O_{4:}$ Vermicompost @ 2.5 t ha^{-1}	157.70^{a}	179.32^{a}	24.06^{a}	158.16^{a}	205.91^{a}	3.35^{a}	1.59	27.93^{a}	13.26^{a}
S.Em. ±	3.38	4.77	0.43	1.80	1.56	0.04	0.05	0.37	0.45
Fertilizers levels (F)									
$F_{1:}$ 75 % RDF	119.62^{c}	140.10^{c}	19.15^{c}	139.56^{c}	184.16^{c}	3.01^{c}	1.49^{a}	25.08^{c}	12.38^{a}
$F_{2:}$ 100 % RDF	139.23^{b}	159.47^{b}	21.69^{b}	147.80^{b}	193.91^{b}	3.15^{b}	1.54^{a}	26.26^{b}	12.80^{a}
F_3: 125 % RDF	156.45^{a}	176.53^{a}	24.73^{a}	159.03^{a}	207.20^{a}	3.36^{a}	1.61^{a}	27.97^{a}	13.38^{a}
S.Em.±	3.31	4.14	0.49	1.34	0.97	3.01	0.05	0.31	0.47
Interaction (O × F)									
$O_1F_{1:}$ FYM @ 5 t ha^{-1}+75 % RDF	104.05^{f}	123.75^{e}	17.56^{g}	134.21^{ef}	178.17^{ef}	2.92^{fg}	1.47^{a}	24.29^{ef}	12.21^{a}
$O_1F_{2:}$ FYM @ 5 t ha^{-1}+100 % RDF	123.66^{d-f}	142.53^{de}	19.50^{e-g}	140.68^{de}	185.57^{d}	3.03^{d-g}	1.50^{a}	25.24^{c-f}	12.46^{a}
O1F_3: FYM @ 5 t ha^{-1}+125 % RDF	141.81^{b-d}	159.79^{b-d}	22.86^{cd}	149.83^{c}	196.45^{c}	3.17^{c-e}	1.55^{a}	26.44^{b-d}	12.94^{a}
$O_2F_{1:}$ FYM @ 7.5 t ha^{-1} + 75 % RDF	133.38^{de}	153.76^{cd}	21.29^{c-f}	147.13^{cd}	192.20^{c}	3.15^{c-f}	1.50^{a}	26.21^{b-e}	12.51^{a}
$O_2F_{2:}$ FYM @ 7.5 t ha^{-1} + 100 % RDF	155.67^{a-c}	176.55^{a-c}	24.19^{bc}	155.30^{dc}	202.63^{b}	3.28^{bc}	1.58^{a}	27.30^{bc}	13.14^{a}
$O_2F_{3:}$ FYM @ 7.5 t ha^{-1} + 125 % RDF	172.74^{a}	193.14^{a}	26.51^{ab}	167.00^{a}	216.63^{a}	3.51^{ab}	1.65^{a}	29.26^{a}	13.78^{a}
$O_3F_{1:}$ VC @ 1.25 t ha^{-1} + 75 % RDF	103.42^{f}	124.85^{e}	17.03^{g}	130.21^{f}	173.91^{f}	2.83^{g}	1.46^{a}	23.57^{f}	12.14^{a}
$O_3F_{2:}$ VC @ 1.25 t ha^{-1} + 100 % RDF	116.34^{ef}	135.63^{de}	18.85^{fg}	136.56^{ef}	181.27^{de}	2.94^{e-g}	1.49^{a}	24.51^{d-f}	12.41^{a}
O_3F_3: VC @ 1.25 t ha^{-1} + 125 % RDF	136.99^{c-e}	156.41^{b-d}	22.32^{c-e}	150.17^{cd}	196.53^{c}	3.20^{cd}	1.55^{a}	26.62^{bc}	12.87^{a}
$O_4F_{1:}$ VC @ 2.5 t ha^{-1} + 75 % RDF	137.61^{c-e}	158.04^{b-d}	20.71^{d-f}	146.71^{cd}	192.37^{c}	3.15^{c-f}	1.52^{a}	26.24^{b-e}	12.68^{a}
$O_4F_{2:}$ VC @ 2.5 t ha^{-1} + 100 % RDF	161.24^{ab}	183.15^{ab}	24.22^{bc}	158.68^{b}	206.17^{b}	3.36^{a-c}	1.58^{a}	28.00^{ab}	13.19^{a}
$O_4F_{3:}$ VC @ 2.5 t ha^{-1} + 125 % RDF	174.24^{a}	196.77^{a}	27.24^{a}	169.10^{a}	219.20^{a}	3.55^{a}	1.67^{a}	29.54^{a}	13.91^{a}
S.Em.±	6.43	8.28	0.85	2.84	2.23	0.07	0.10	0.62	0.90
Absolute control (C)	65.91^{g}	89.02^{f}	12.36^{h}	110.60^{g}	144.00^{f}	2.45^{h}	1.12^{b}	20.43^{g}	9.31^{b}
S.Em.±	6.21	7.96	0.84	2.74	2.16	0.07	0.10	0.6	0.89

DAS: Days after sowing, RDF: Recommended dose of fertilizer , 100 % RDF: 125: 75: 37.5 kg N: P_2O_5: K_2O ha^{-1}

throughout the crop growth period resulting in increased uptake of nutrients that leads to better growth of plant and as a result higher grain and stover yields.

Effect of fertilizer levels

Application of 125 % RDF recorded significantly higher grain (3,619 kg ha^{-1}) and stover yield (71.7 q ha^{-1}) compared to application of 75 and 100 % RDF presented in the Table 2. The increase in grain yield of popcorn due to 125 % RDF over 75 and 100 % RDF and was to an extent of 23 % and 11 %, respectively. The increased grain and stover yield was due to higher yield attributing characters *viz.*, number of grains cob^{-1} (571.60), cob length (16.73 cm), cob girth (10.36 cm), 1000 seed weight (150.13 g) and grain yield plant^{-1} (126.90 g). The increase in yield was attributed to higher growth *viz.*, plant height (32.9, 166.9 and 176.2 cm), number of leaves (5.18, 13.0 and 7.47, respectively), leaf area per plant (26.50, 67.37 and 38.55 dm^2 plant^{-1}), LAI (2.21, 5.61 and 3.21) at 40, 80 DAS and at harvest. The higher TDMA (24.73, 159.03 and 207.20 g plant^{-1} at 40, 80 DAS and at harvest, respectively) was mainly due to higher AGR and CGR (3.36 g day^{-1} and 27.97 g m^{-2}day^{-1}) at 40- 80 DAS. Increased growth parameters might be attributed to increased nitrogen, phosphorous and potassium uptake at harvest (Table 3) as evidenced by increased available soil nitrogen, phosphorous and potassium. Similar results are observed by Hanjanatti (2017) revealed that the progressive growth and yield attributes in maize lead to better source sink relationship in maize that in turn gave higher grain and stover yield of maize due to higher fertilizer levels at various crop growth stage. Another study by Kanannavar (2013) at Dharwad revealed that higher amount of fertilizer has significant influence on effective translocation of accumulated photosynthates from source to sink and better development of grains.

Effect of integrated nutrient management

Application of VC @ 2.5 t ha^{-1} + 125 % RDF recorded significantly higher grain yield (4,003 kg ha^{-1}) and found at par with application of FYM @ 7.5 t ha^{-1} + 125 % RDF (3,983 kg ha^{-1}). The increase in grain yield due to application of VC @ 2.5 t ha^{-1} + 125 % RDF and FYM @ 7.5 t ha^{-1} + 125 % RDF over the application of VC @ 1.25 t ha^{-1} + 75 % RDF was to the tune of 56.0 % and 55.0 %, respectively. The increased grain and stover yield was due to higher yield attributing characters presented in Table 2 *viz.*, number of grains cob^{-1} (631.47) , cob length (18.49 cm), cob girth (10.86 cm), 1000 seed weight (157.00 g). The increase in grain and yield attributes was due to higher

Table 2. Yield and yield attributes of popcorn as influenced by organic manures and fertilizer levels

Treatments	No. grains cob^{-1}	Cob length (cm)	Cob girth (cm)	1000 seed weight (g)	Grain yield (g plant^{-1})	Grain yield (kg ha^{-1})	Stover yield (q ha^{-1})
Organic levels (O)							
O_1: FYM @ 5 t ha^{-1}	424.37^{b}	13.36^{c}	9.29^{b}	142.94^{c}	104.07^{b}	2949^{b}	65.4^{b}
O_2: FYM @7.5 t ha^{-1}	546.14^{a}	16.08^{a}	10.17^{a}	147.44^{b}	126.11^{a}	3494^{a}	69.8^{a}
O_3: Vermicompost @ 1.25 t ha^{-1}	428.12^{b}	14.79^{b}	9.28^{b}	142.22^{c}	103.09^{b}	2860^{b}	64.2^{b}
O_4: Vermicompost @ 2.5 t ha^{-1}	554.76^{a}	17.01^{a}	10.23^{a}	150.33^{a}	129.78^{a}	3541^{a}	69.8^{a}
S.Em. ±	9.17	0.30	0.11	0.82	2.29	50	0.9
Fertilizers levels (F)							
F_1: 75 % RDF	409.43^{c}	13.58^{c}	9.12^{c}	141.83^{b}	103.52^{c}	278 ^{c}	62.7^{c}
F_2: 100 % RDF	484.01^{b}	15.62^{b}	9.75^{b}	145.25^{b}	116.87^{b}	3233^{b}	67.5^{b}
F_3: 125 % RDF	571.60^{a}	16.73^{a}	10.36^{a}	150.13^{a}	126.90^{a}	3619^{a}	71.7^{a}
S.Em.±	14.27	0.16	0.10	1.22	1.35	32	0.82
Interaction (O × F)							
O_1F_1: FYM @ 5 t ha^{-1}+75 % RDF	343.33^{d}	11.38^{f}	8.56^{f}	141.33^{cd}	95.87^{e}	2683^{ef}	61.5^{d}
O_1F_2: FYM @5 t ha^{-1}+100 % RDF	423.71^{cd}	13.78^{e}	9.50^{c-e}	142.67^{cd}	102.51^{de}	2848de	64.8^{cd}
O1F_3: FYM @ 5 t ha^{-1}+125 % RDF	506.07^{bc}	14.91^{d}	9.81^{b-e}	144.83^{b-d}	113.82^{c}	3314^{c}	69.8^{a-c}
O_2F_1: FYM @ 7.5 t ha^{-1} + 75 % RDF	473.97^{bc}	13.80^{e}	9.45^{b}	143.33^{cd}	107.97^{cd}	2944^{cd}	65.0^{cd}
O_2F_2: FYM @ 7.5 t ha^{-1} + 100 % RDF	539.10^{ab}	16.80^{bc}	10.21^{ab}	147.00^{bc}	129.37^{b}	3553^{b}	70.8^{ab}
O_2F_3: FYM @ 7.5 t ha^{-1} + 125 % RDF	625.36^{a}	17.63^{ab}	10.84^{a}	152.00^{ab}	141.00^{a}	3983^{a}	73.5^{ab}
O_3F_1: VC @ 1.25 t ha^{-1} + 75 % RDF	342.16^{d}	13.64^{e}	8.79^{f}	138.00^{d}	95.90^{e}	2556^{f}	60.8^{d}
O_3F_2: VC @ 1.25 t ha^{-1} + 100 % RDF	418.70^{cd}	14.85^{d}	9.13^{ef}	142.00^{cd}	103.83^{de}	2850de	62.8^{d}
O_3F_3: VC @ 1.25 t ha^{-1} + 125 % RDF	523.51^{b}	15.89^{cd}	9.94^{b-d}	146.67^{bc}	109.53^{cd}	3175^{c}	68.9^{bc}
O_4F_1: VC @ 2.5 t ha^{-1} + 75 % RDF	478.27^{bc}	15.50^{d}	9.67^{b-e}	144.67^{b-d}	114.33^{c}	2942^{d}	63.3^{d}
O_4F_2: VC @ 2.5 t ha^{-1} + 100 % RDF	554.54^{ab}	17.04^{b}	10.15^{bc}	149.33^{bc}	131.77^{b}	3680^{b}	71.4^{ab}
O_4F_3: VC @ 2.5 t ha^{-1} + 125 % RDF	631.47^{a}	18.49^{a}	10.86^{a}	157.00^{a}	143.23^{a}	4003^{a}	74.7^{a}
S.Em. ±	25.04	0.40	0.20	2.15	3.19	73	1.6
Absolute control (C)	243.24 ^{e}	10.56 ^{g}	7.80 ^{g}	134.67 ^{e}	79.07 ^{f}	1378 ^{g}	54.2^{e}
S.Em.±	25.31	0.39	0.20	2.72	3.10	69	1.6

RDF: Recommended dose of fertilizer , 100 % RDF: 125: 75: 37.5 kg N: P_2O_5: K_2O ha^{-1}

values of growth and growth parameters (Table 1 (a) and Table 1 (b) as evidenced by higher values of growth components *viz.*, plant height (35.0, 180.5 and 188.4 cm), number of leaves per plant (5.53, 13.53 and 7.93), leaf area (29.73, 74.88 and 43.18 dm^2 plant^{-1}), LAI (2.49, 6.24 and 3.60) at 40, 80 DAS and at harvest, LAD (174.24 and 196.77 days) at 40- 80 DAS and 80 DAS – harvest. The higher TDMA (27.24, 169.10 and 219.20 g plant^{-1} at 40, 80 DAS and at harvest, respectively) resulted higher AGR and CGR (3.55 g day^{-1} and 29.54 g m^{-2}day^{-1}) at 40- 80 DAS. The increased growth and yield was also attributed to increased nitrogen, phosphorous and potassium uptake at harvest (Table 3) as evidenced by increased soil available nitrogen , phosphorous and (table No. 3). These results were in agreement with findings of Shah and Wani (2017) revealed that higher grain yield was attributed to better and continuous optimum supply of nutrients throughout all the crop growth stages. Combination of organic and inorganic fertilizers helped to release nutrients at right time of crop requirement and increased translocation of photosynthates from source to sink for better development of grains. Another study by Mahapatra *et al.* (2018) revealed that yield boosted with use of integrated nutrient management due to its favourable effect in increase in crop growth, the combined effect of inorganic and organic mixed with biofertilizer has synergistic effect in availability of nutrient in soluble form throughout growing period. However, enhancement of yield might be due to the effective utilization of applied nutrients which increased sink capacity and higher nutrient uptake by crop.

Quality parameters of popcorn as influenced by organics and fertilizer levels are presented in the Table 3. Significant variation in popping percentage, expansion volume and flake size of popcorn was not observed due to the interaction of organics and fertilizer levels. Similar results are observed by the Weatherwax (1922) and Kanannavar (2013) revealed that quality parameters of popcorn was not appreciably affected due to nutrient management and dependent on genotypes, moisture content of kernel and maintenance of heat at the time of popping of kernels.

Economics

The economics of popcorn were significantly influenced by organics are presented in Table 4. Significantly higher net returns recorded with application of VC @ 2.5 t ha^{-1} + 125 % RDF (₹ 91,824 ha^{-1}) and found at par with application of FYM @ 7.5 t ha^{-1} + 125 % RDF (₹ 91,676 ha^{-1}) has a result of higher grain and stover yield. Lowest net returns was recorded with absolute control (₹ 21,437 ha^{-1}) due to its lower productivity both in grain and stover yield. Application of FYM @ 7.5 t ha^{-1} + 125 % RDF recorded significantly higher BC ratio (2.73) and found on par with application VC @ 2.5 t ha^{-1} along with application of 100 and 125 % RDF (2.58 and 2.72, respectively). Lowest BC ratio was recorded with absolute control (1.70) and was due to lower grain yield and lower net returns. These results were in agreement with findings of Ravi *et al.* (2012) revealed that higher gross returns, net returns and B:C obtained with these treatments were ultimately due to higher productivity in terms of yield.

Table 3. Quality, nutrient uptake, available nutrients status in soil as influenced by organic manures and fertilizer levels in popcorn

Treatments	Popping percent (%)	Expansion volume (ml/g)	Flake size (ml)	Nitrogen uptake (kg ha^{-1})	Phosphorus uptake (kg ha^{-1})	Potassium uptake (kg ha^{-1})	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Organic levels (O)									
O$_{1:}$ FYM @ 5 t ha^{-1}	90.63^{a}	15.04^{a}	2.28^{a}	156.60^{b}	27.24^{b}	132.52^{b}	219.33^{b}	30.76^{b}	263.89^{c}
O$_{2:}$ FYM @ 7.5 t ha^{-1}	90.68^{a}	15.42^{a}	2.37^{a}	187.46^{a}	33.84^{a}	151.42^{a}	241.89^{a}	34.97^{a}	280.56^{ab}
O$_{3:}$ Vermicompost @ 1.25 t ha^{-1}	90.27^{a}	14.98^{a}	2.31^{a}	154.46^{b}	26.52^{b}	130.50^{b}	216.22^{a}	30.28^{b}	265.28^{bc}
O$_{4:}$ Vermicompost @ 2.5 t ha^{-1}	90.74^{a}	15.33^{a}	2.36^{a}	189.16^{a}	34.29^{a}	158.90^{a}	242.51^{b}	35.42^{a}	281.94^{a}
S.Em. ±	0.83	0.12	0.03	3.01	0.53	8.06	1.88	0.55	4.62
Fertilizers levels(F)									
F$_{1:}$ 75 % RDF	90.44^{a}	15.00^{a}	2.29^{a}	151.94^{c}	26.00^{c}	128.55^{c}	210.13^{c}	29.22^{c}	261.46^{c}
F$_{2:}$ 100 % RDF	90.48^{a}	15.13^{a}	2.34^{a}	172.67^{b}	30.52^{b}	145.05^{b}	231.92^{b}	33.00^{b}	273.96^{b}
F$_{3}$: 125 % RDF	90.83^{a}	15.45^{a}	2.36^{a}	191.15^{a}	34.90^{a}	156.40^{a}	247.92^{a}	36.35^{a}	283.33^{a}
S.Em.±	0.40	0.15	0.03	2.41	0.52	4.62	2.11	0.61	4.39
Interaction (O × F)									
O$_1$F$_{1:}$ FYM @ 5 t ha^{-1}+75 % RDF	90.83^{a}	14.80^{a}	2.23^{a}	135.57^{g}	24.03^{fg}	123.55^{cd}	198.33^{f}	27.92^{de}	254.17^{bc}
O$_1$F$_{2:}$ FYM @ 5 t ha^{-1}+100 % RDF	90.37^{a}	15.00^{a}	2.31^{a}	158.37^{ef}	26.44^{ef}	131.50^{cd}	219.33^{e}	30.63	262.50^{a-c}
O1F$_3$: FYM @ 5 t ha^{-1}+125 % RDF	90.70^{a}	15.33^{a}	2.31^{a}	175.87^{cd}	31.25^{cd}	142.52^{a-d}	240.33^{c}	33.75^{bc}	275.00^{a-c}
O$_2$F$_{1:}$ FYM @ 7.5 t ha^{-1} + 75 % RDF	90.33^{a}	15.20^{a}	2.34^{a}	170.17^{de}	29.32^{de}	131.00^{cd}	224.00^{de}	31.25^{cd}	270.83^{a-c}
O$_2$F$_{2:}$ FYM @ 7.5 t ha^{-1} + 100 % RDF	90.13^{a}	15.33^{a}	2.37^{a}	187.76^{bc}	34.39^{bc}	154.75^{a-c}	245.00^{bc}	36.17^{ab}	283.33^{ab}
O$_2$F$_{3:}$ FYM 7.5 t ha^{-1} + 125 % RDF	91.59^{a}	15.73^{a}	2.39^{a}	204.45^{a}	37.81^{a}	168.50^{ab}	256.67^{ab}	37.50^{ab}	287.50^{a}
O$_3$F$_{1:}$ VC @ 1.25 t ha^{-1} + 75 % RDF	90.16	14.80^{a}	2.27^{a}	132.95^{g}	21.59^{g}	120.50^{d}	196.00^{f}	26.04^{e}	250.00^{c}
O$_3$F$_{2:}$ VC @ 1.25 t ha^{-1} + 100 % RDF	90.27^{a}	14.93^{a}	2.32^{a}	150.76^{f}	25.57^{f}	129.10^{cd}	217.00^{e}	28.96^{de}	266.67^{a-c}
O$_3$F$_3$: VC @ 1.25 t ha^{-1} + 125 % RDF	90.39^{a}	15.20^{a}	2.34^{a}	179.66^{cd}	32.42^{b-d}	141.89^{a-d}	235.67^{cd}	35.83^{ab}	279.17^{a-c}
O$_4$F$_{1:}$ VC @ 2.5 t ha^{-1} + 75 % RDF	90.45^{a}	15.20^{a}	2.30^{a}	169.05^{de}	29.05^{de}	139.15^{b-d}	222.20^{e}	31.67^{cd}	270.83^{a-c}
O$_4$F$_{2:}$ VC @ 2.5 t ha^{-1} + 100 % RDF	91.14^{a}	15.27^{a}	2.38^{a}	193.81^{ab}	35.69^{ab}	164.85^{ab}	246.33^{a-c}	36.25^{ab}	283.33^{ab}
O$_4$F$_{3:}$ VC @ 2.5 t ha^{-1} + 125 % RDF	90.63^{a}	15.53^{a}	2.41^{a}	204.63^{a}	38.13^{a}	172.70^{a}	259.00^{a}	38.33^{a}	291.67^{a}
S.Em.±	1.06	0.28	0.07^{a}	4.95	1.0	11.04	3.93	1.14	8.54
Absolute control (C)C	90.58^{a}	14.50^{a}	2.21^{a}	103.80^{h}	16.63^{h}	100.17^{e}	165.67^{g}	23.75^{f}	250.00^{d}
S.Em.±	1.01	0.31	0.07	5.03	1.13	10.70	3.90	1.11	8.50

RDF: Recommended dose of fertilizer, 100 % RDF: 125: 75: 37.5 kg N: P_2O_5: K_2O ha^{-1} and Initial nutrient status: 277: 35.22: 366.55 kg N: P_2O_5: K_2O ha^{-1}

Table 4. Economics of popcorn as influenced by organic manures and fertilizer levels

Treatments	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	BC ratio
O$_1$F$_{1:}$ FYM @ 5 t ha^{-1}+75 % RDF	45992	98224^{ef}	52232^{ef}	2.14^{c}
O$_1$F$_{2:}$ FYM @ 5 t ha^{-1}+100 % RDF	47564	104218de	56654^{ef}	2.19^{c}
O1F$_3$: FYM @ 5 t ha^{-1}+125 % RDF	49135	120890^{c}	71755^{cd}	2.46^{b}
O$_2$F$_{1:}$ FYM @ 7.5 t ha^{-1} + 75 % RDF	49742	107590^{d}	57848^{e}	2.16^{c}
O$_2$F$_{2:}$ FYM @ 7.5 t ha^{-1} + 100 % RDF	51314	129325^{b}	78011^{bc}	2.52^{b}
O$_2$F$_{3:}$ FYM @ 7.5 t ha^{-1} + 125 % RDF	52885	144562^{a}	91676^{a}	2.73^{a}
O$_3$F$_{1:}$ Vermicompost @ 1.25 t ha^{-1} + 75 % RDF	44106	93699^{f}	49592^{f}	2.12^{c}
O$_3$F$_{2:}$ Vermicompost @ 1.25 t ha^{-1} + 100 % RDF	45678	104148de	58470^{e}	2.28^{c}
O$_3$F$_{3:}$ Vermicompost @ 1.25 t ha^{-1} + 125 % RDF	47249	115951^{c}	68702^{d}	2.45^{b}
O$_4$F$_{1:}$ Vermicompost @ 2.5 t ha^{-1} + 75 % RDF	50356	107392^{d}	57035^{e}	2.13^{c}
O$_4$F$_{2:}$ Vermicompost @ 2.5 t ha^{-1} + 100 % RDF	51928	133801^{b}	81873^{b}	2.58^{ab}
O$_4$F$_{3:}$ Vermicompost @ 2.5 t ha^{-1} + 125 % RDF	53499	145324^{a}	91824^{a}	2.72^{a}
S.Em.±	-	2569	2569	0.05
Absolute control (C)	30587	52022^{g}	21437^{g}	1.70^{d}
S.Em.±	-	2419	2419	0.05

RDF: Recommended dose of fertilizer , 100 % RDF: 125: 75: 37.5 kg N: P_2O_5: K_2O ha^{-1}

Popcorn seed cost - ₹ 3,500 q^{-1}, dry stover cost - ₹ 70.

Conclusion

Integrated plant nutrient management system is efficient and judicious use of all the major sources of plant nutrients in an integrated manner, it was concluded that application of VC @ 2.5 t ha^{-1} + 156.25: 93.75: 46.87 kg N: P_2O_5: K_2O ha^{-1} or FYM @ 7.5 t ha^{-1} + 156.25: 93.75: 46.87 kg N: P_2O_5: K_2O ha^{-1} recorded higher growth, yield and economics in popcorn. In this context both organic manuring and mineral nutrition have to be given adequate attention under rainfed situation in Northern transition tract of Karnataka.

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