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Effect of Integrated Nutrient Management on Growth, Yield Attributes and Yield of Maize and Wheat in Maize-Wheat Cropping System in Mid Hills of Himachal Pradesh

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ABSTRACT

An experiment was conducted for two consecutive years from kharif (2015) to rabi (2016-17) at the experimental farm of Department of Agronomy, Forages and Grassland Management, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. Experiment laid out in randomized block design with three replications comprising seven treatments i.e. 50% nitrogen through FYM + 50% nitrogen through inorganic fertilizer; 50% nitrogen through fortified vermicompost + 50% nitrogen through inorganic fertilizer; 50% nitrogen through vermicompost + 50% nitrogen through inorganic fertilizer; 25% nitrogen through FYM + 75% nitrogen through inorganic fertilizer; 25% nitrogen through fortified vermicompost + 75% nitrogen through inorganic fertilizer; 25% nitrogen through vermicompost + 75% nitrogen through inorganic fertilizer and recommended dose of NPK through inorganic fertilizer and three treatments i.e. 50% (recommended dose of NPK through inorganic fertilizers; 75% RDF and 100% RDF. All the seven treatments given to maize crop will act as main plot treatments for wheat during rabi season. Plant growth and yield attributes as well as yield were recorded. Integrated organics and inorganics application to maize significantly improved the growth, yield attributes, grain and stover yield of maize at par with 100% inorganics. Treatments receiving organics for substituting 25% N either through fortified vermicompost or vermicompost (T_5 and T_6) gave higher numerical values among the organics and inorganics combinations. Residual effects on wheat growth, yield and yield attributes were not significant. Fertilizer application to wheat with 100% NPK significantly enhanced wheat growth, yield and yield attributes.

Key words: *Integrated nutrient management, Growth, Yield attributes, yield, Maize and wheat*

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INTRODUCTION

Maize and wheat have become very popular cereal crops in India. The productivity of cereals are largely dependent on its nutrient management. Globally, maize is known as Miracle crop and "Queen of Cereals" due to high genetic yield potentials than any other cereals counterpart[9]. In India, maize is cultivated in an area of 8.69 million hectare having production of 21.81 million tonnes with a productivity of 2509 kg ha^{-1}[1]. Maize is the major crop of the Himachal Pradesh. The production of maize, which was cultivated on an area 0.30 million hectare having production 0.67 million tonnes with a productivity of 2270 kg ha^{-1}[1]. Wheat is an important post monsoon crop of the country as India is ranking second in wheat production with an area of 30.2 million hectare having production of 93.5 million tonnes along with productivity of 3093 kg ha^{-1}[1]. In Himachal Pradesh, also wheat among other cereals occupies the largest area of about 0.35 million hectare with total production of 0.68 million tonnes along with a productivity of 1968 kg ha^{-1}[1]. Maize (*Zea mays* L.) - wheat (*Triticum aestivum* L.) are belongs to family Poaceae is the most dominant cropping system in the State of Himachal Pradesh, contributing about 85 per cent of the total food grain production in the state. The productivity of this existing cropping system in small and marginal farmer's field is very low[5] besides having lower cropping intensity as the fields remain idle for nearly three months. Nitrogen being a major plant food nutrient plays a vital role in plant growth system. It is an integral part of protein, enzyme and nucleic acids which are responsible for the development of chlorophyll and ultimately the nitrogen supply to plants is of utmost importance in all the crops. The organic sources besides supplying N, P and K also make unavailable source of elemental nitrogen, bound phosphorus, micronutrients, and decomposed plant residues into available form to facilitate plant to absorb the nutrients. But the combined use of chemical fertilizers along with various organic sources is capable of improving soil quality and crop productivity on long term basis. The enriched vermicompost is a mixture of vermicompost, natural minerals and microorganisms. The chemical fertilizers alone cannot meet the requirement of crops and cropping systems, because of their high cost and less residual effects of chemicals, hence there is increasing trend towards use of organic manures. Incorporation of organic matter either in the form of crop residues or farmyard manure/ vermicompost/compost are vital for supplementing plant nutrients and maintenance of soil fertility, as it is an important soil component which influences the physical, chemical and biological properties of soil. Incorporation of organic manures influence soil enzymatic activity either because of the composition of the added materials or they increase microbial activity of the soil[6]. The objective behind this experimentation was to increase the yield of maize and wheat and productivity along with use of integrated nutrient management.

Table1. N, P and K content of FYM, vermicompost and fortified vermicompost

Parameter	Maize 2015			Maize 2016		
	FYM	Vermi-compost	Fortified vermi-compost	FYM	Vermi-compost	Fortified vermi-compost
Nitrogen (%)	0.91	1.80	2.02	0.93	1.90	2.12
Phosphorus (%)	0.33	0.70	0.85	0.35	0.90	0.87
Potassium (%)	0.67	1.24	1.30	0.65	1.30	1.27

MATERIAL AND METHODS

Location:

The experimental farm is situated at $32^0 6'$ N latitude and $76^0 3'$ E longitude and at an elevation of 1290 m above mean sea level in North Western Himalaya. The area represents the mid-hill zone of Himachal Pradesh. The region is endowed with mild summers and cool winters. The mean weekly meteorological observations recorded at the meteorological observatory of the Department of Agronomy, Forages and Grassland Management, College of Agriculture, CSK HPKV, Palampur during the crop growth period. The meteorological data revealed that maximum mean monthly temperature ranged from 14.3º C to 32.7º C and minimum from 2.4º C to 19.7º C during the first year, and 11.6º C to 32.9º C and 2.8º C to 19.6º C in second year of experimentation. The relative humidity ranged between 27.4 per cent to 94.1 per cent during 2015-16 and between 42.3 per cent to 95.5 per cent during 2016-17, with highest humidity recorded during the month of August. This month also received highest amount of rainfall during both the years which was 416 mm in 2015 and 315 mm in 2016. The maximum bright sunshine hours were recorded during 2^{nd} week of May (77.03 hours) in 2015 and last week of April (84.05 hours) in 2016.

Experimental design:

Seven integrated nutrient management treatments in maize *viz.*, 50% N through FYM + 50% N through inorganic fertilizer; 50% N through fortified vermicompost + 50% N through inorganic fertilizer; 50% N through vermicompost + 50% N through inorganic fertilizer; 25% N through FYM + 75% N through inorganic fertilizer; 25% N through fortified vermicompost + 75% N through inorganic fertilizer; 25% N through vermicompost + 75% N through inorganic fertilizer and recommended dose of NPK through inorganic fertilizers and three treatments in wheat *viz.*, 50% RDF (recommended dose of NPK through inorganic fertilizers); 75% RDF and 100% RDF constituting 21 treatment combinations, were evaluated for two consecutive years commencing from *kharif*, 2015 to *rabi*, 2016-17 at Palampur in maize-wheat cropping sequence. In the first *kharif* season seven fertility treatments in maize were evaluated in randomized block design with three replications. Subsequently from *rabi*, 2015-16, the treatments in maize were assigned to main plots and those in wheat to sub plots in a split plot design.

Agronomic details:

Maize variety K 25 Gold (Kanchan Ganga) with spacing 60 x 20 cm. Wheat variety HPW-236 is recommended for mid hills area for timely sowing in irrigated areas with spacing 22.5 x 5 cm. Before sowing of maize, FYM as per treatment was applied at the time of final field preparation. Vermicompost and fortified vermicompost were applied at seeding below the seeding furrows in their respective treatments. The N, P and K fertilizers were applied as per treatment through urea, SSP and MOP @ 120, 60 and 40 kg ha^{-1}, recommend dose of fertilizer respectively. One third N and whole P_2O_5 and K_2O were applied at the time of sowing. The remaining two third of N was applied in two equal splits, one at knee-high and the other at tasseling stage. In wheat crop, N, P and K were applied @ 120, 60 and 30 kg ha^{-1} recommend dose of fertilizer through urea IFFCO 12:32:16 and urea respectively. Half N and whole P_2O_5 and K_2O were applied at the time of sowing. The remaining nitrogen was top dressed after one month of sowing. Nitrogen as per treatment was given by organics and phosphorus and potassium supplied by these organics were adjusted accordingly as per treatment.

Details of observations recorded:

Plant height- five plants of maize were selected at random from the net plot area of each plot and were tagged. The height was measured at 30 days interval and at harvest after sowing of crop. The mean height was obtained by dividing the total plant height of five plants by [5]. Leaf area index; the leaf area was measured at 30 days interval and at harvest of crop on the basis of a sample of five plants at each stage. The leaf area was measured with leaf area metre and then leaf area index was worked out using the formula given by Redford; Dry matter accumulation; periodic dry matter accumulation at 30 days interval and at harvest after sowing of crop was recorded. Five plants were randomly selected from sampling rows. These plants were cut from the ground level, chopped and oven dried at 70°C till constant weight for 72 hours. After drying, their weight was recorded. The mean dry weight per plant was worked out by dividing the total weight with the number of plants. Final plant population number m^{-2}; the total numbers of plants present in the net plot were counted before harvesting. Then plant population m^{-2} was determined. Length of cob; five plants of maize were selected at random from the net plot area of each plot. The size of cob was measured with meter rod from base to tip of cob. The mean size of cob was obtained by dividing the total cob size of five plants by five. Diameter of cob; five plants of maize were selected at random from the net plot area of each plot. Diameter of cob was measured from three places of cob and width of cob expressed in centimeter after averaging the three reading. Number of cobs $plant^{-1}$; all the cobs in net plots were counted and the number was divided by the total number of plants in the net plot to get the number of cobs per plant. Number of grains cob^{-1}; the grains in each of the five randomly selected cobs were shelled and then counted with the help of seed counter. Average of total grains obtained from five selected cobs was recorded to get mean number of grains per cob. Grain weight cob^{-1}; five cobs were randomly selected from each plot and threshed. The grains were cleaned and weighted the mean weight of five cobs grains were recorded as grain yield per cob. 1000-grain weight; a homogenous grain sample from five randomly selected cobs was taken and one thousand grains were counted with the help of seed counter. The weight of these grains was recorded as test weight. Grain yield; the produce from the plots was harvested and dried in sun, the total weight was taken as biological yield, the grains from the produce of net plot were then separated manually, cleaned and the weight recorded which was taken as yield from net plot. The net plot yield was then converted into kg ha^{-1}. Stover yield; the weight of stover from net plot area was recorded after harvesting and sun drying the harvested produce for seven days in order to reduce the moisture content. The stover yield was then expressed in kg ha^{-1}. Harvest index; harvest index was worked out by grain yield divieded by biological yield. Number of spikes m^{-2}; the number of spikes per running were counted at the time of harvesting and expressed as number of spikes m^{-2} by multiplying with factor 4.44. Length of spike; the average length of spike from five randomly selected spikes was recorded from the base of lowest spikelet to the tip of the top most spikelet. Number of spikelets $spike^{-1}$; five spikes were selected at random from the produce of each net plot. Then number of spikelets per spike were counted and averaged. Number of grains $spike^{-1}$; total number of grains from five randomly selected was counted and a mean was counted and a mean was calculated and recorded. Grain weight per spike; five spikes were randomly selected from each plot and threshed. The grains were cleaned and weighed; the mean weight of five spikes was given as grain weight per spike. 1000-grain weight; a homogenous grain sample from five randomly selected cobs was taken and one thousand grains were counted with the help of seed counter. The weight of these grains was recorded as test weight. Statistical analysis; the data so obtained and collected from the field and laboratory experiments were subjected to the statistical analysis as per the procedures given by Gomez and Gomez and were tested at 5 per cent level of significance to interpret the treatment differences.

RESULTS AND DISCUSSION

Maize Growth studies

The data on growth parameters *viz.*, plant height, leaf area index and dry matter accumulation were recorded at different growth stages (30 DAS, 60 DAS, 90 DAS and at harvest stage). The trends in plant height, leaf area index and dry matter accumulation were depicted in Fig 1a; b, 2a; b and 3a; b respectively, Plant height, leaf area index and dry matter accumulation increased progressively upto harvest. The leaf area index increased up to 60 days after sowing then decreased due to senescence.

Plant height

Treatments in maize gave significant variations in plant height at maximum height stage (i.e. 90 DAS) during both the years. Significantly taller plants were recorded with the application of recommended dose of fertilizer (T_7) remaining at par with 25% N through fortified vermicompost + 75% N through fertilizer (T_5) and 25% N through vermicompost + 75% N through fertilizer (T_6). However, 25% N through fortified vermicompost + 75% N through fertilizer (T_5) and 25% N through vermicompost + 75% N through fertilizer (T_6) were statistically equal to 25% N through farm yard manure + 75% N through fertilizer (T_4). The effect of fortified vermicompost and chemical fertilizer in combination was more pronounced with the advancement of crop growth indicating better effect on plant height of maize. It might be attributed to improved fertility status of the soil through microbial activities and better utilization of plant nutrients by maize. Organic manures especially vermicompost supply nutrients to plant roots in balanced amount and stimulate growth, increase organic matter content of the soil including the 'humic substances' that affect nutrient accumulation and promote root growth which lead to better growth of maize plants resulting in taller plants. Similar were the results reported by Siminis *et al*.[23] and Canellas *et al*. Treatment of 50% N through farm yard manure + 50% N through fertilizer (T_1) recorded shortest plants. However, it was at par with 50% N through fortified vermicompost + 50% N through fertilizer (T_2) and 50% N through vermicompost + 50% N through fertilizer (T_3) during both the years (Table 2).

Table 2. Treatment effects on plant height (cm) at harvest, leaf area index at 60 (DAS) and dry matter accumulation (g plant^{-1}) at harvest of maize during 2015 and 2016

Treatment		Plant height (cm)		Leaf area index		Dry matter accumulation (g plant^{-1})	
In Maize		2015	2016	2015	2016	2015	2016
T_1	FYM_{50N} + $Fertilizer_{50N}$	172.8	176.9	3.13	3.24	102.6	105.7
T_2	Forti. VC_{50N} + $Fertilizer_{50N}$	183.5	182.2	3.33	3.36	111.3	114.8
T_3	VC_{50N} + $Fertilizer_{50N}$	178.8	180.4	3.27	3.31	107.2	109.4
T_4	FYM_{25N} + $Fertilizer_{75N}$	185.4	184.8	3.30	3.35	107.7	112.3
T_5	Forti. VC_{25N} + $Fertilizer_{75N}$	195.0	191.7	3.45	3.45	118.9	116.5
T_6	VC_{25N} + $Fertilizer_{75N}$	193.4	189.0	3.41	3.42	113.3	114.7
T_7	RDF	197.2	193.8	3.43	3.50	121.4	118.6
SEm±		3.68	3.05	0.06	0.056	2.6	2.4
CD(P=0.05)		11.33	9.4	0.20	0.17	8.02	7.28
In wheat							
F_1	50% RDF	-	182.2	-	3.34	-	111.8
F_2	75% RDF	-	185.8	-	3.39	-	113.4
F_3	100% RDF	-	188.5	-	3.40	-	114.2
SEm±		-	2.46	-	0.034	-	1.04
CD(P=0.05)		-	NS	-	NS	-	NS

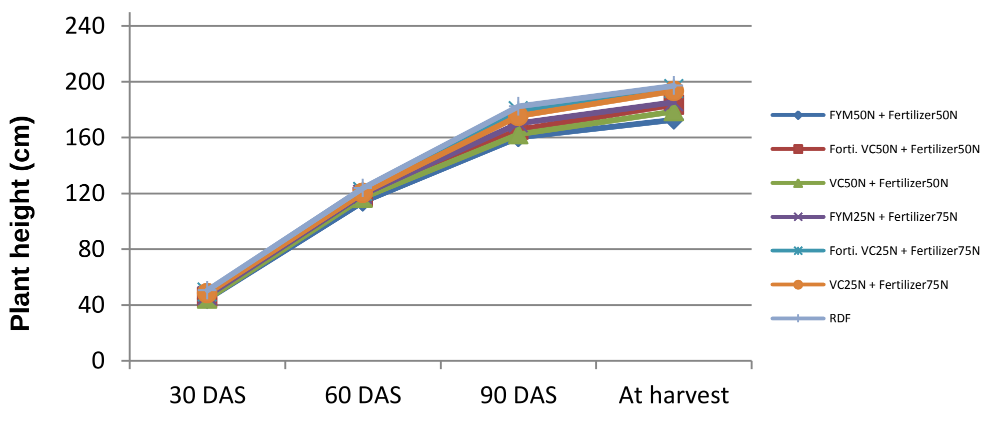
FYM= Farm yard manure, Forti= Fortified, 50N= 50% Nitrogen, VC= Vermicompost, RDF= Recommended dose of fertilizer

Leaf area index (LAI)

Treatments in maize gave significant variation in LAI at maximum LAI stage (i.e. 60 DAS) during 2015 as well as 2016. Significantly higher LAI was recorded with the application of recommended dose of fertilizer (T_7). However, it remained at par with 50% N through fortified vermicompost + 50% N through fertilizer (T_2), 50% N through vermicompost + 50% N through fertilizer (T_3), 25% N through farm yard manure + 75% N through fertilizer (T_4), 25% N through fortified vermicompost + 75% N through fertilizer (T_5) and 25% N through vermicompost + 75% N through fertilizer (T_6) during 2015 except 50% N through vermicompost + 50% N through fertilizer (T_3) during 2016. The beneficial effect of organic/vermicompost on leaf area index might be due to synthesis of certain phytohormones and vitamins and more interception of solar radiation and synthesis of more chlorophyll which resulted in higher leaf area index in maize. Similar results has also been reported by Nehra *et al.* [14] and Sanwal *et al.*[21]. Treatment of 50% N through farm yard manure + 50% N through fertilizer (T_1) had lower LAI (Table 2).

Dry matter accumulation (g plant^{-1})

Data showed that effect of treatments in maize significantly influenced dry matter accumulation. Significantly higher dry matter accumulation was recorded with the application of recommended dose of fertilizer (T_7) which remained at par with 25% N through fortified vermicompost + 75% N through fertilizer (T_5) during 2015. However, during second year except 50% N through farm yard manure + 50% N through fertilizer (T_1) and 50% N through vermicompost + 50% N through fertilizer (T_3) all other treatments were statistically equal to recommended dose of fertilizer (T_7). In association with soil microorganisms, organic manures are known to help in synthesis of certain phytohormones and vitamins which promote the growth and development of crops. Due to favorable conditions during the crop growth period and slow release of nutrients associated with vermicompost might have resulted in higher concentration of nutrients in plant cells resulting in higher dry matter accumulation. Application of 50% nutrients through fertilizers resulted in quick and readily availability of major nutrients like N, P and K to plants at earlier stages of plant growth. Similar increase in growth parameters with combined application of nutrients along with organic/manures/vermicompost was reported by Prasad and Naik[17]. Fifty per cent N through farm yard manure + 50% N through fertilizer (T_1) resulted in lower dry matter accumulation (Table 2).



(a) Plant height of maize, during 2015

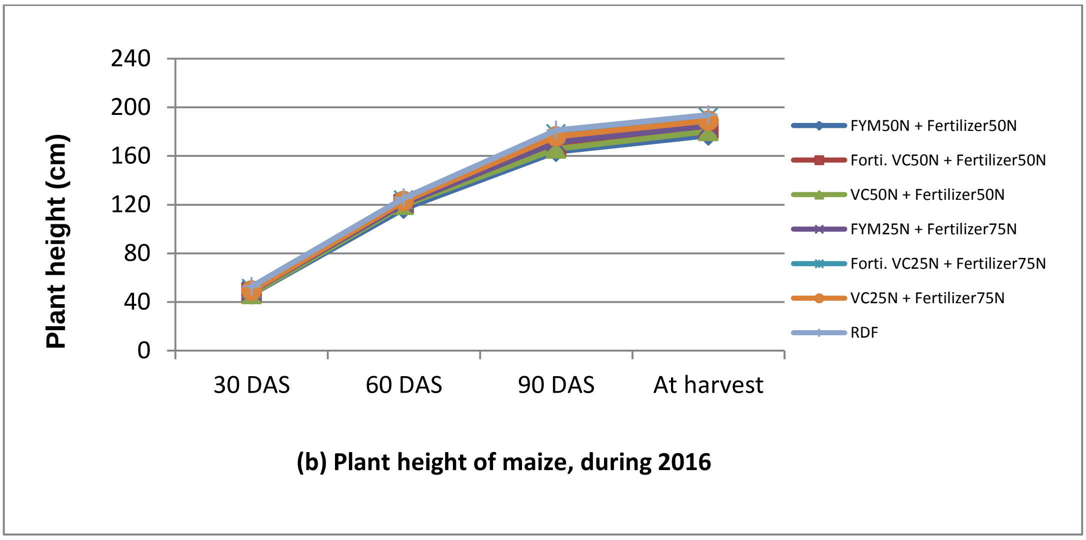
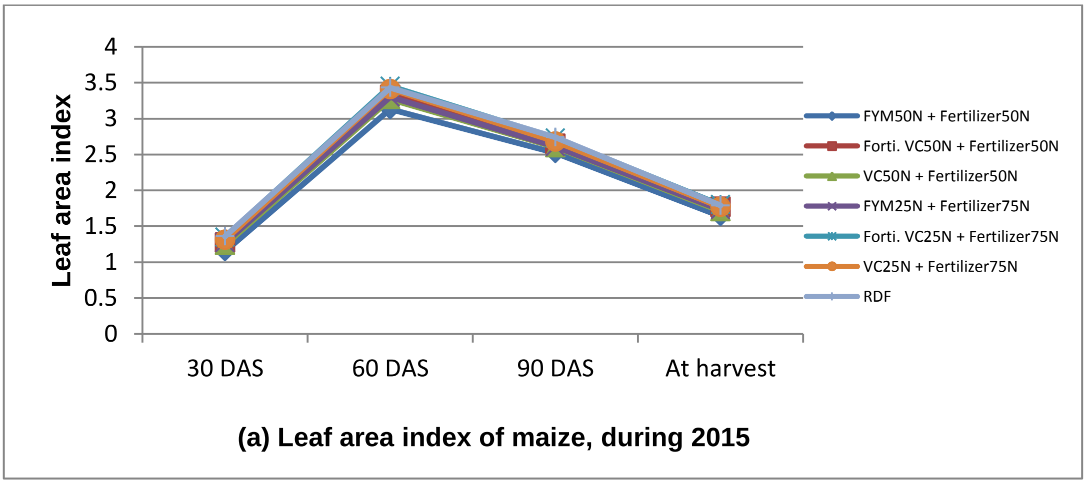


Fig. 1: Treatment effects on plant height of maize, (a) 2015 and (b) 2016



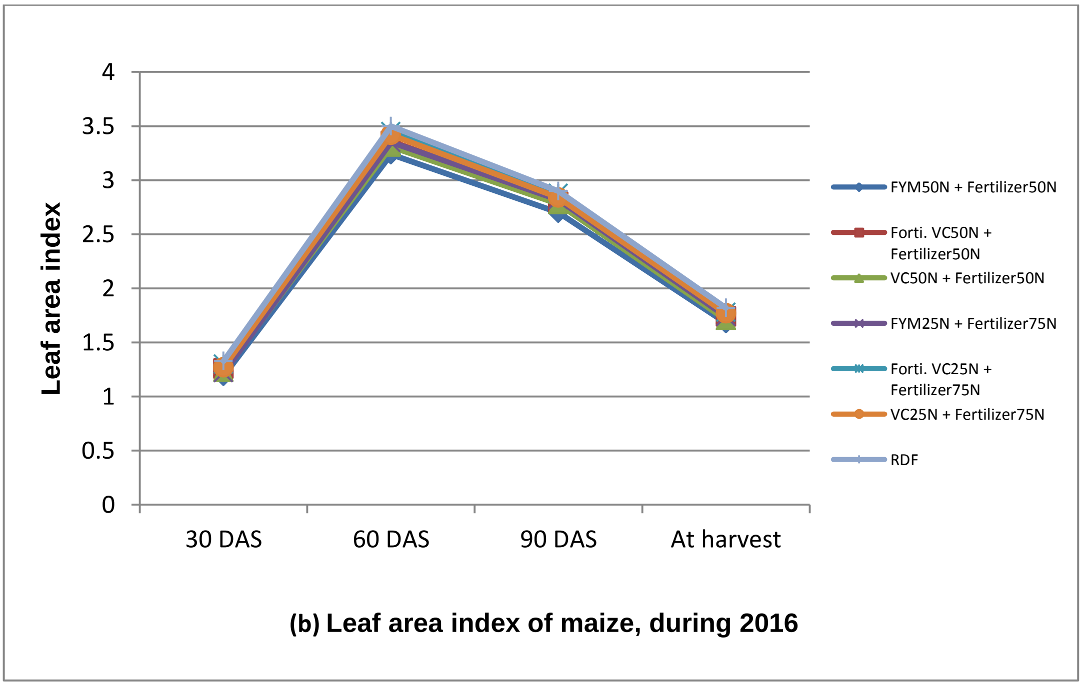
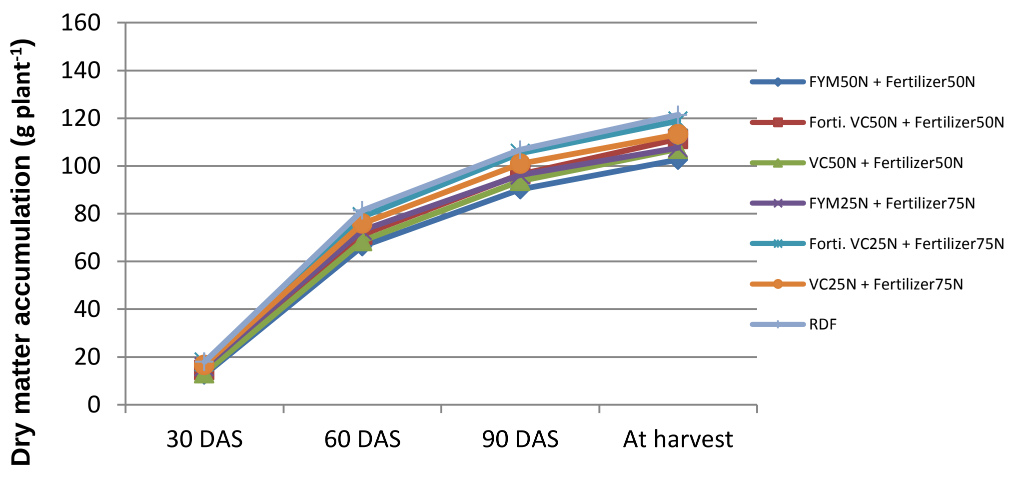
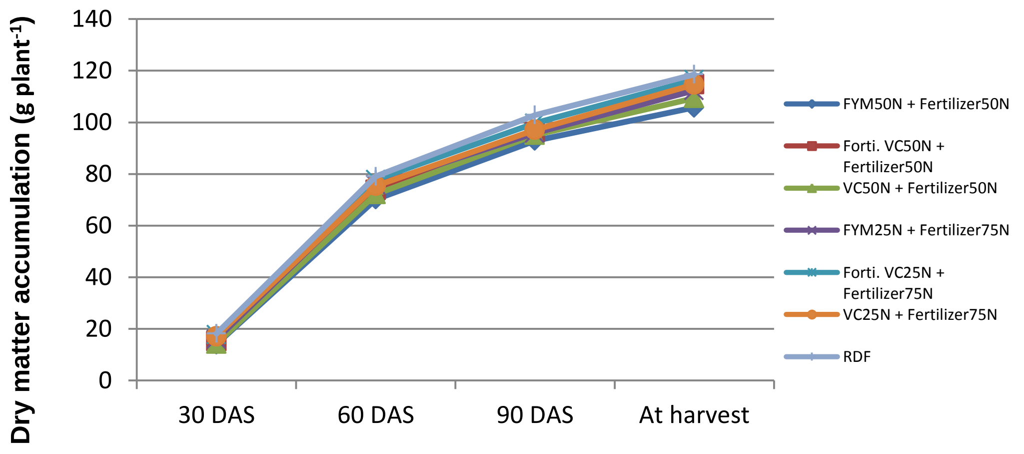


Fig. 2: Treatment effects on leaf area index of maize, (a) 2015 and (b) 2016



(a) Dry matter accumulation of maize, during 2015



(b) Dry matter accumulation of maize, during 2016

Fig. 3: Treatment effects on dry matter accumulation of maize, (a) 2015 and (b) 2016

Yield attributes

Length of cob (cm)

The data presented in (Table 3) revealed significant effect of treatments on length of cob during 2016 only. Recommended dose of fertilizers (T_7) had significantly longer cobs. All other treatments except 50% N through farm yard manure + 50% N through fertilizer (T_1) were at par with recommended dose of fertilizers (T_7). The increase in length of cob might be attributed to the availability of more nitrogen and other nutrients in sufficient quantity from the applied and native pool. These results suggested that adequate supply of nutrients from both organic and inorganic source throughout vegetative growth was necessary for proper cob development in maize as reported by Samsami[20].

Diameter of cob (cm)

Data revealed significant influence of treatments in maize on diameter of cob during both the years of experimentation. Recommended dose of fertilizers (T_7) had significantly higher diameter of cob. All other treatments except 50% N through farm yard manure + 50% N through fertilizer (T_1) and 25% N through farm yard manure + 75% N through fertilizer (T_4) remained at par with former treatment during both the years of study. The increase in diameter of cob might be attributed to the availability of more nutrients. These results suggested that adequate supply of nutrients from both organic and inorganic source was necessary for proper cob diameter in maize as reported by Chapagain[4] and Samsami[20]. T_1 had lower diameter of cob during both the years of experimentation (Table 3).

Number of cobs plant^{-1}

The observations presented in (Table 3) indicated significant influence of integrated nutrient management treatments in maize on the number of cobs per plant during both the years of investigations. Application of recommended dose of fertilizer (T_7) remaining at par with 25% N through fortified vermicompost + 75% N through fertilizer (T_5) and 25% N through vermicompost + 75% N through fertilizer (T_6) resulted in significantly higher number of cobs per plant during 2015. However, during 2016 treatments 50% N through fortified vermicompost + 50% N through fertilizer (T_2) and 25% N through farm yard manure + 75% N through fertilizer (T_4) were also found on par with former treatments. This might be due to better nutrient uptake and development of the plant and cob due to combined application of mineral fertilizer along with organic material as reported by Prasad *et al*.[16].

Number of grains cob^{-1}

A perusal of data in (Table 3) showed that application of 25% N through fortified vermicompost + 75% N through fertilizer (T_5) resulted in significantly higher number of grains cob^{-1} during 2015. However, this treatment was at par with 50% N through fortified vermicompost + 50% N through fertilizer (T_2), 25% N through farm yard manure + 75% N through fertilizer (T_4), 25% N through vermicompost + 75% N through fertilizer (T_6) and recommend dose of fertilizers (T_7). Similar trend was observed in second year. This might be due to better nutrient uptake and development of the plant and cob due to combined application of mineral fertilizer and organic manures as reported by Prasad *et al*.[16].

Grain weight cob^{-1} (g)

Data depicted in (Table 3) showed that almost similar trend was observed as that for number of grains per cob during both years. Treatments *viz.*, 50% N through fortified vermicompost + 50% N through fertilizer (T_2), 25% N through farm yard manure + 75% N through fertilizer (T_4), 25% N through fortified vermicompost + 75% N through fertilizer (T_5) and 25% N through vermicompost + 75% N through fertilizer (T_6) remained at par with RDF (T_7). Hence, the significant increase in grain weight per cob, was noticed, which can be attributed due to more grain weight per cob. These results also in conformity with the earlier finding of Barod *et al*.[3].

Table 3. Treatment effects on yield attributes of maize crop during 2015 and 2016

Treatment		Length of cob (cm)		Diameter of cob (cm)		No. of cobs plant^{-1}		No. of grains cob^{-1}		Grain weight cob^{-1} (g)		1000-grain weight (g)	
In maize		2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
T_1	FYM_{50N} + $Fertilizer_{50N}$	15.62	16.18	3.60	3.75	1.12	1.14	276.0	290.7	67.6	74.2	244.4	248.4
T_2	Forti. VC_{50N} + $Fertilizer_{50N}$	16.41	16.60	3.72	3.84	1.15	1.17	285.9	296.4	71.7	77.3	250.8	252.7
T_3	VC_{50N} + $Fertilizer_{50N}$	15.37	16.42	3.68	3.81	1.12	1.15	280.4	292.3	69.8	75.4	248.7	250.4
T_4	FYM_{25N} + $Fertilizer_{75N}$	15.74	16.38	3.63	3.76	1.14	1.16	282.4	294.4	71.7	76.4	253.8	253.7
T_5	Forti. VC_{25N} + $Fertilizer_{75N}$	16.37	16.80	3.77	3.88	1.18	1.20	294.5	302.4	75.2	80.0	255.2	255.6
T_6	VC_{25N} + $Fertilizer_{75N}$	15.96	16.68	3.70	3.82	1.17	1.18	287.0	296.4	73.1	78.2	254.6	254.0
T_7	RDF	16.33	17.12	3.75	3.92	1.18	1.21	293.9	304.2	75.4	81.3	256.6	258.2
SEm±		0.55	0.26	0.03	0.04	0.01	0.02	4.04	3.62	1.72	1.56	4.48	3.68
CD(P=0.05)		NS	0.80	0.09	0.13	0.02	0.05	12.42	11.2	5.29	4.8	NS	NS
In wheat													
F_1	50% RDF	-	16.48	-	3.80	-	1.16	-	294.0	-	75.8	-	250.9
F_2	75% RDF	-	16.64	-	3.83	-	1.18	-	297.2	-	78.3	-	254.1
F_3	100% RDF	-	16.66	-	3.85	-	1.18	-	298.8	-	78.4	-	254.8
SEm±		-	0.18	-	0.02	-	0.01	-	2.18	-	1.22	-	2.42
CD(P=0.05)		-	NS	-	NS	-	NS	-	NS	-	NS	-	NS

FYM= Farm yard manure, Forti=Fortified, 50N = 50% Nitrogen, VC= Vermicompost, RDF= Recommended dose of fertilizer

1000-grain weight (g)

Integrated nutrient management treatments in maize could not significantly influence 1000-grain weight of maize being the varietal character could not be affected by management levels (Table 3). However, numerical values were slightly higher at recommended dose of fertilizer.

Grain yield (kg ha^{-1})

Application of 25% N through fortified vermicompost + 75% N through fertilizer (T_5) resulted in significantly higher grain yield of maize during 2015. However, it remained at par with recommended dose of fertilizer (T_7), 25% N through vermicompost + 75% N through fertilizer (T_6), 25% N through farm yard manure + 75% N through fertilizer (T_4), 50% N through fortified vermicompost + 50% N through fertilizer (T_2) and 50% N through vermicompost + 50% N through fertilizer (T_3). Increase in grain yield due to fortified vermicompost (T_5) over 50% N through farm yard manure + 50% N through fertilizer (T_1) was 18.72% during 2015. Almost similar trend was observed during second year of study except 50% N through farm yard manure + 50% N through fertilizer (T_1) remained inferior to 50% N through fortified vermicompost + 50% N through fertilizer (T_2) and 50% N through vermicompost + 50% N through fertilizer (T_3) respectively. Hence, fortified vermicompost (T_5) registered an increase in grain yield over farm yard manure (T_1) to the tune of 12.78% (Table 4). The increase in yield under these treatments was because of favorable influence of nutrient application on the growth and yield attributes of maize. The improvement in grain yield under treatments involving organic/vermicompost might be due to the improvement in soil physico-chemical properties (*viz.*, pH, bulk density, infiltration rate and microbial biomass carbon) and optimum availability of nutrients and organic carbon which acted as the growth and yield enhancing characters of maize crop. Further the grain yield of maize mainly depends upon the final plant population and yield of individual plant, the latter in turn depends upon the number of ears per plant and the weight of grains per cob which resulted in higher grain yield in maize. Similar results were also reported by Saini and Kumar[19] and Nasab *et al*.[13].

Stover yield (kg ha^{-1})

The perusal of data in (Table 4) showed that different fertility treatments in maize also significantly influenced the stover yield of maize. Almost similar trend in stover yield was observed as it was noticed in grain yield of maize. Application of vermicompost and FYM at different levels T_2 to T_6 remained at par with recommended dose of fertilizer (T_7) during 2015. Further, 25% N through fortified vermicompost + 75% N through fertilizer (T_5) and recommend dose of fertilizers (T_7) were found superior to 50% N through farm yard manure + 50% N through fertilizer (T_1). During second year also (T_5), (T_6) and (T_7) remaining at pat with each other were found superior to all other treatments. These results are in close conformity with the finding of Channabasanagowda *et al*. and Saini and Kumar[19] who have shown that the slight different action of vermicompost or FYM substitution may be because of slow release of nutrient from them due to slow mineralization. Fertilizers applied in wheat did not have any significantly influence on stover yield of maize. Also the interaction effects were not significant on stover yield of maize.

Harvest index (%)

Integrated nutrient management treatment in maize and wheat could not significantly influence harvest index of maize being the genetic character (Table 4). The interaction was also not significant on harvest index of maize.

Table 4. Treatment effects on grain yield (kg ha^{-1}), stover yield (kg ha^{-1}) and harvest index (%) of maize crop during, 2015 and 2016

Treatment		Grain yield (kg ha^{-1})		Stover yield (kg ha^{-1})		Harvest index (%)	
In maize		2015	2016	2015	2016	2015	2016
T_1	FYM_{50N} + $Fertilizer_{50N}$	3611	3819	5416	5671	39.98	40.24
T_2	Forti. VC_{50N} + $Fertilizer_{50N}$	3859	4048	5789	6032	40.00	40.15
T_3	VC_{50N} + $Fertilizer_{50N}$	3785	3849	5612	5819	40.28	39.81
T_4	FYM_{25N} + $Fertilizer_{75N}$	3877	4093	5770	5942	40.18	40.78
T_5	Forti. VC_{25N} + $Fertilizer_{75N}$	4287	4307	6224	6384	40.75	40.28
T_6	VC_{25N} + $Fertilizer_{75N}$	4122	4209	6066	6244	40.82	40.26
T_7	RDF	4275	4413	6282	6523	40.50	40.35
SEm±		180	144	220	176	0.56	0.43
CD(P=0.05)		554	444	677	542	NS	NS
In wheat							
F_1	50% RDF	-	4036	-	5993	-	40.24
F_2	75% RDF	-	4124	-	6096	-	40.35
F_3	100% RDF	-	4156	-	6174	-	40.23
SEm±		-	78	-	114	-	0.16
CD(P=0.05)		-	NS	-	NS	-	NS

FYM= Farm yard manure, Forti= Fortified, 50N= 50% Nitrogen, VC= Vermicompost, RDF= Recommended dose of fertilizer

Residual effect of fertility treatments in wheat did not significantly influence plant height, dry matter accumulation and leaf area index of maize at harvest. Treatments in maize and wheat did not interact significantly in influencing plant height, dry matter accumulation and leaf area index of maize at harvest.

Growth studies (wheat)

Plant height (cm)

The data on plant height of wheat recorded at 30, 60, 90, 120, 150 days after sowing and at harvest and maximum plant height has been presented in Table. The trends in plant height with advancement in growth stage as influenced due to fertility treatments in wheat have been depicted in Fig 4a;b.

Table 5. Treatment effects on initial plant population (m^{-2}), plant height (cm) and dry matter accumulation (g m^{-2}) at harvest of wheat

Treatment		Plant height (cm)		Dry matter accumulation (g m^{-2})	
In maize		2015-16	2016-17	2015-16	2016-17
T_1	FYM_{50N} + $Fertilizer_{50N}$	103.2	108.0	952.6	980.4
T_2	Forti. VC_{50N} + $Fertilizer_{50N}$	101.1	105.9	938.6	975.1
T_3	VC_{50N} + $Fertilizer_{50N}$	101.4	109.2	933.4	964.3
T_4	FYM_{25N} + $Fertilizer_{75N}$	102.5	106.4	941.4	966.7
T_5	Forti. VC_{25N} + $Fertilizer_{75N}$	100.9	105.2	930.5	960.4
T_6	VC_{25N} + $Fertilizer_{75N}$	102.2	107.0	925.1	952.4
T_7	RDF	99.8	107.8	920.7	950.4
SEm±		1.2	1.5	12.5	11.5
CD(P=0.05)		NS	NS	NS	NS
In wheat					
F_1	50% RDF	97.8	102.4	885.4	911.2
F_2	75% RDF	102.0	107.1	945.7	974.4
F_3	100% RDF	104.9	111.7	972.7	1007.1
SEm±		0.8	1.1	7.4	9.8
CD(P=0.05)		2.3	3.3	22.9	28.4

FYM= Farm yard manure, Forti=Fortified, 50N = 50% Nitrogen, VC= Vermicompost, RDF= Recommended dose of fertilizer

There was progressive increase in plant height of wheat with advancement in growth. The maximum plant height was recorded at harvest.

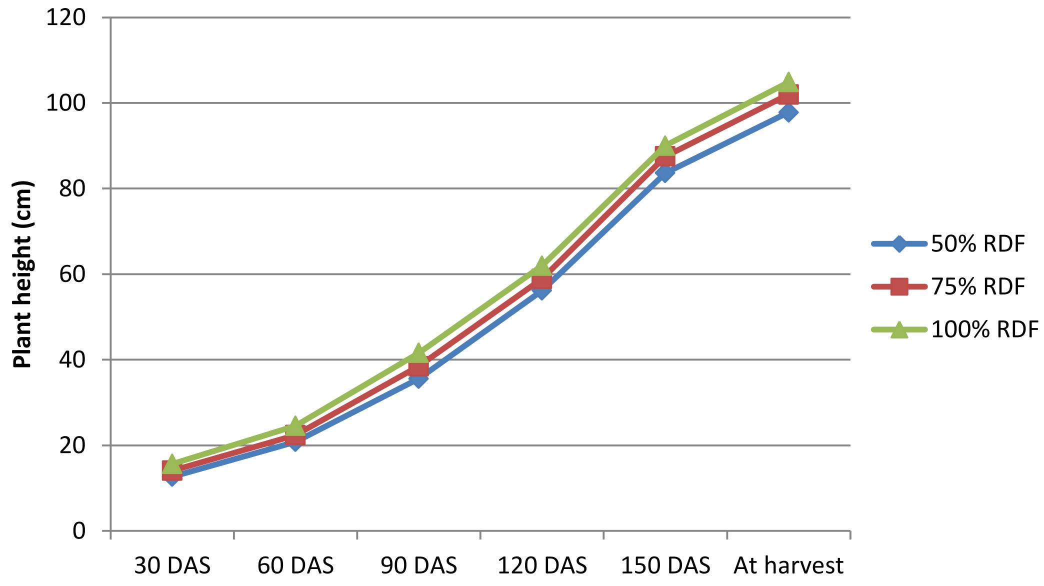
A perusal of the data indicated that application of integrated nutrient management treatments in maize did not result in any significant difference in plant height of wheat during both the years of experimentation. However, inorganic fertilizers applied to wheat significantly influenced plant height of wheat during both the years of study. Plant height increased consistently with increasing fertilizer level from 50% recommended dose of fertilizer (F_1) to 100% recommended dose of fertilizers (F_3) at harvest during both the years of experimentation. Since plant nutrition is directly related with plant growth and development and hence, better nutrition with increasing levels of fertilizer, increased plant height at increasing rate i.e. 30 days after sowing to harvest stage. This clearly indicates that higher level of nutrients helped in the elongation of stem due to development of cells, rapid cell division and cell elongation in meristematic region of plant. Therefore, taller plants were recorded in 100% recommended dose of fertilizer (F_3) application as compared to lower levels of nutrition. Similar results were also reported by Malghani and Sharma *et al*.[22]. Treatments in maize and wheat did not interact significantly in influencing plant height of wheat during both the years (Table 5) and Fig 4a; b.

Dry matter accumulation

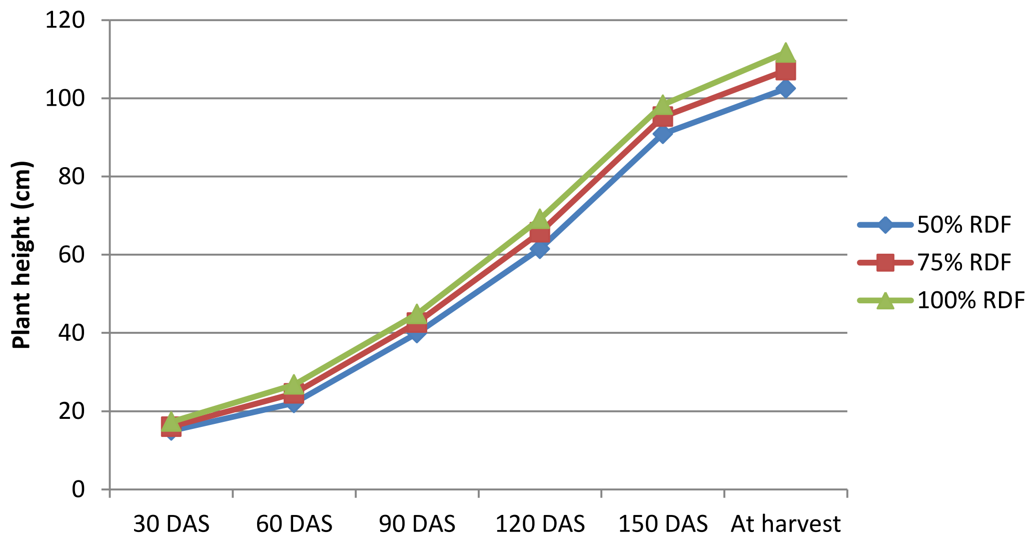
The observations on dry matter accumulation of wheat were recorded at 30, 60, 90, 120, 150 days after sowing and at harvest. The seasonal trends in dry matter accumulation by wheat crop have been depicted in Fig 5a; b. A perusal of the Fig revealed slow initial growth in terms of dry matter accumulation from sowing till 90 DAS. Thereafter, there was rapid increase in dry matter accumulation of wheat from 90 DAS onwards. The maximum dry matter of wheat was realized at harvest stage. The maximum dry matter accumulation by wheat as affected due to fertility treatments in maize and wheat are also presented in (Table 5) to interpret the treatment differences.

Residual effect of nutrient management treatment in maize could not significantly influence dry matter accumulation of wheat during both the years of study (Table 5). Though, numerical values of dry matter accumulation increased with the increasing amounts of organic fertilizers.

Fertility treatments applied in wheat significantly influenced the dry matter accumulation of wheat. The data at harvest stage showed that the dry matter accumulation increased consistently and significantly with increase in fertility levels from 50% to 100% recommended dose of fertilizers (F_3). Fertilizers are the key factors in influencing the growth, development and ultimately the yield of crops in addition to other growth factors interacting with each other. Among the various nutrients influencing the crop growth, N, P and K are most critical under irrigated conditions. Adequate supply of these three major nutrients is essential for crops owing to their wide spread deficiencies in most of the soils and the vital role they play in plant metabolism, growth and development and therefore, higher dry matter was recorded with higher fertility level. Similar results were also reported by Kumar[11]. The interaction effects of fertility treatments in maize and wheat were not significant on dry matter accumulation of wheat during both the years of study.

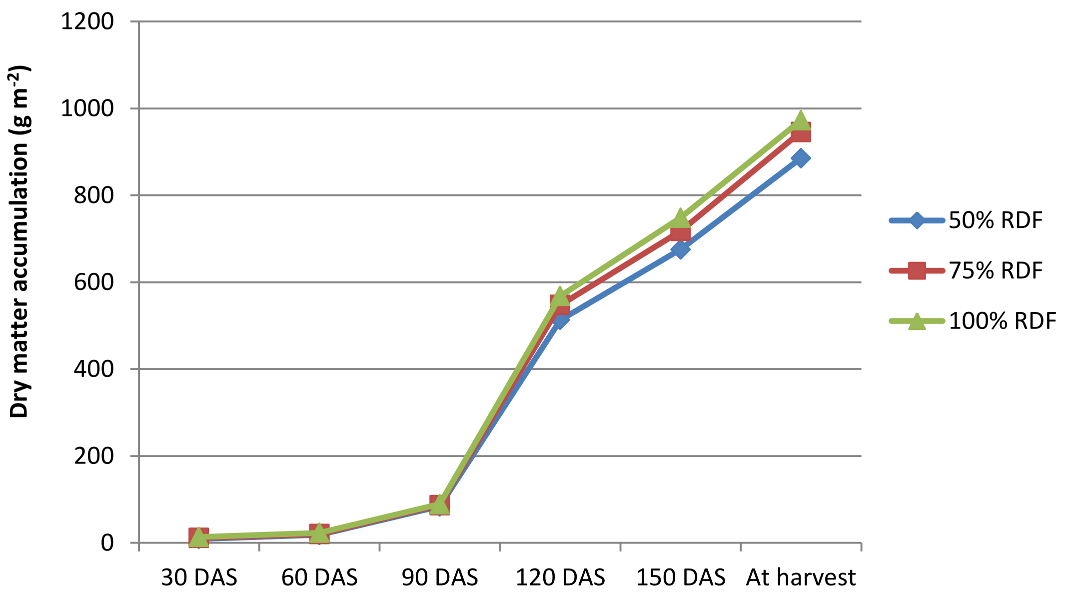


(a) Plant height of wheat, during 2015-16

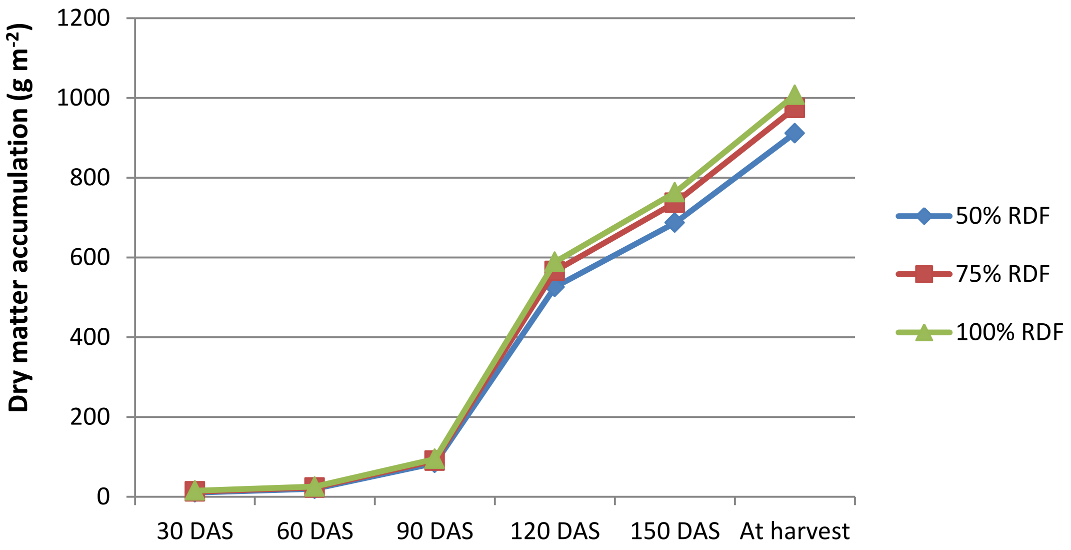


(b) Plant height of wheat, during 2016-17

Fig. 4: Treatment effects on plant height of wheat, (a) 2015-16 and (b) 2016-17



(a) Dry matter accumulation of wheat, during 2015-16



(b) Dry matter accumulation of wheat, during 2016-17

Fig. 5: Treatment effects on dry matter accumulation of wheat, (a) 2015-16 and (b) 2016-17

Studies at harvest

Yield attributes

The data on different yield attributes of wheat *viz.*, number of shoots (m^{-2}) at harvest, number of spikes m^{-2}, length of spike, number of spikelets spike^{-1}, number of grains spike^{-1}, grain weight spike^{-1} and 1000-grain weight have been presented in (Table 6) .

Number of shoots (m^{-2}) at harvest

The data pertaining to number of shoots m^{-2} at harvest of wheat have been given in (Table 6) The results revealed that application of integrated nutrient management treatments in maize did not affect statistically number of shoots of wheat at harvest during both the years. However, fertility treatments in wheat significantly influenced number of shoots of wheat during both the years of study. Application of 100% recommended dose of fertilizer resulted in significantly higher number of shoots of wheat at harvest during both the years. This was followed by 75% and 50% RDF during both the years. The interaction effect between fertility treatments in maize and wheat for number of shoots of wheat were not significant during both the years.

Number of spikes m^{-2}

There was no significant difference among treatments applied to maize on number of spikes m^{-2} in wheat during both the years (Table 6).

However, fertilizer treatments to wheat showed that application of 100% recommended dose of fertilizer (F_3) in wheat resulted in significantly highest number of spikes m^{-2} of wheat followed by 75% recommended dose of fertilizer (F_2) and latter followed by 50% recommended dose of fertilizer (F_1) during both the years of study. The improvement in growth parameters *viz.*, plant height and dry matter accumulation due to application of 100% RDF, acted as initial capital which might have results in better improvement of all the yield attributes of wheat. Similar results have also been reported by Yousefi and Sadeghi[26]. The interaction effect between fertility treatments in maize and wheat for number of spikes m^{-2} of wheat were not significant during both the years of experimentation.

Length of spike (cm)

A perusal of the data in (Table 6) indicated that application of different treatments in maize could not bring about significant residual effect on length of spike of wheat during both the years of experimentation. Fertility treatments in wheat significantly influenced the length of spike during both the years. Application of 100% recommended dose of fertilizer (F_3) gave significantly highest length of spike of wheat during 2015-16. However, 75% recommended dose of fertilizer (F_2) was comparable to 100% RDF (F_3) during 2016-17. Similar results were reported by Tababtabaei and Ranjbar[25] and Dwivedi *et al*.[7]. The interaction between fertility treatments in maize and wheat was not significant for length of spike.

Number of spikelets spike^{-1}

The data in (Table 6) indicated that application of different treatments in maize did not significantly influence number of spikelets per spike of wheat during both the years of experimentation.

Application of 100% recommended dose of fertilizer (F_3) resulted in significantly highest number of spikelets per spike of wheat followed by 75% and 50% RDF. However, application of 100% (F_3) and 75% recommended dose of fertilizer (F_2) were comparable to each other during 2016-17. The increase in spikelets per spike might be due to the application of inorganic sources of nutrients which increased the availability of NPK & improved soil physico-chemical properties of soil. Similar results have been reported by Ram and Mir[18] and Singh[24]. Fertility treatments in maize and wheat were not interacted significantly for number of spikelets per spike during both the years.

Number of grains spike^{-1}

The data presented in (Table 6) indicated that application of integrated nutrient management treatments in maize did not result in any significant difference on number of grains per spike of wheat during both the seasons.

Direct application of 100% recommended dose of fertilizer (F_3) resulted in significantly higher number of grains per spike of wheat during 2015-16. However, This treatment was statistically at par with 75% recommended dose of fertilizer (F_2) during 2016-17. The lower number of grains per spike of wheat were recorded under 50% RDF during both the years of investigation. Interaction effects between fertility treatments in maize and wheat were not significant during both the years. The improvement in number of grains per spike might be due to stimulated vegetative growth of wheat on account of adequate and prolonged supply of essential nutrients. Similar results have been reported by Meena *et al*.[12] and Ihsan and Hassan[8] who also observed increase in number of grains per spike due to inorganic sources of nutrients.

Grain weight spike^{-1}

Application of integrated nutrient management treatments in maize had no significant affect on grain weight per spike of wheat during 2015-16 and 2016-17 (Table 6).

During *rabi* season application of 100% recommended dose of fertilizer (F_3) and 75% recommended dose of fertilizer (F_2) remaining at par with each other resulted in significantly higher grain weight per spike over 50% RDF during 2015-16. However, 75% recommended dose of fertilizer (F_2) and 100% recommended dose of fertilizer (F_3) were at par with each other during second year. Similar results were reported by Kumar *et al*.[10] and Ram and Mir[18]. The interaction for grain weight per spike was not significant during both the years.

Table 6. Treatment effects on yield attributes of wheat during 2015-16 and 2016-17

Treatment	Number of shoots (m^{-2})		No. of spikes (m^{-2})		Length of spike (cm)		No. of spikelets spike^{-1}		No. of grains spike^{-1}		Grain weight spike^{-1}		1000 grain weight (g)	
In maize	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
T_1 FYM_{50N} + $Fertilizer_{50N}$	245.7	263.7	243.6	256.3	12.0.	12.1	19.4	20.1	43.8	45.7	1.85	1.94	40.73	41.12
T_2 Forti. VC_{50N} + $Fertilizer_{50N}$	236.8	258.3	235.7	252.4	11.8	12.0	19.3	20.2	42.4	45.9	1.76	1.92	39.78	40.88
T_3 VC_{50N} + $Fertilizer_{50N}$	234.0	254.7	232.3	248.3	11.8	11.9	19.3	19.5	42.8	45.2	1.75	1.88	39.16	40.56
T_4 FYM_{25N} + $Fertilizer_{75N}$	241.0	256.1	239.4	251.3	11.8	12.0.	19.6	19.6	44.4	45.5	1.84	1.90	40.41	40.38
T_5 Forti. VC_{25N} + $Fertilizer_{75N}$	240.4	252.4	237.0	247.1	11.8	11.8	19.6	19.3	44.5	44.9	1.82	1.89	39.22	40.76
T_6 VC_{25N} + $Fertilizer_{75N}$	237.1	251.0	234.0	245.9	11.8	11.8	19.3	19.8	43.3	45.8	1.78	1.90	39.54	40.21
T_7 RDF	234.2	249.7	232.7	243.4	11.8	11.8	19.2	20.4	42.4	46.1	1.74	1.92	39.24	40.48
SEm±	4.9	5.3	4.8	5.4	0.1	0.16	0.44	0.54	1.16	0.72	0.058	0.05	0.84	0.52
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
In wheat														
F_1 50% RDF	221.7	236.8	220.6	228.7	11.6	11.7	18.0	18.7	40.5	44.0	1.67	1.83	38.84	40.06
F_2 75% RDF	240.6	257.3	238.4	251.4	11.9	12.0	19.5	20.0	43.8	45.9	1.81	1.92	39.96	40.64
F_3 100% RDF	253.0	271.3	250.1	267.6	12.04	12.1	20.7	20.9	46.0	46.8	1.89	1.97	40.39	41.18
SEm±	3.6	4.2	3.7	4.3	0.11	0.11	0.56	0.37	0.96	0.42	0.034	0.038	0.42	0.29
CD(P=0.05)	10.4	12.2	10.7	12.5	0.32	0.32	1.62	1.07	2.78	1.22	0.10	0.11	1.22	0.84

FYM= Farm yard manure, Forti=Fortified, 50N = 50% Nitrogen, VC= Vermicompost, RDF= Recommended dose of fertilizer

1000-grain weight (g)

A cursory glance of the data in (Table 6) revealed that application of integrated nutrient management treatments in maize had not significantly influenced 1000-grain weight of wheat during both the years of experimentation.

Fertility treatments applied in wheat resulted in significant variation in 1000 grain weight. Treatment receiving 100% recommended dose of fertilizer (F_3) remaining at par with 75% recommended dose of fertilizer (F_2) gave significantly higher 1000-grain weight over 50% RDF (F_1) during both the years of study. Seventy five per cent (F_2) and 50% RDF (F_1) were found at par with each other during both the years. The weight of individual grains and the number of filled grains are governed by the grain growth supported by concurrent CO_2 assimilation during the grain filling phase rather than by the stored reserve of carbohydrates during the vegetative phase. Thus, better nutrition of plants associated with increased fertilization helped in maintaining significantly better vegetative growth leading to greater interception of solar radiation by the crops and ultimately contributed towards the significant increase in number of filled grains.

These results also corroborate the findings of Patidar and Mali[15] and Sharma[22]. The interaction between treatments in maize and wheat could not bring any significant effect on 1000- grain weight during both the years.

Grain yield, straw yield and harvest index

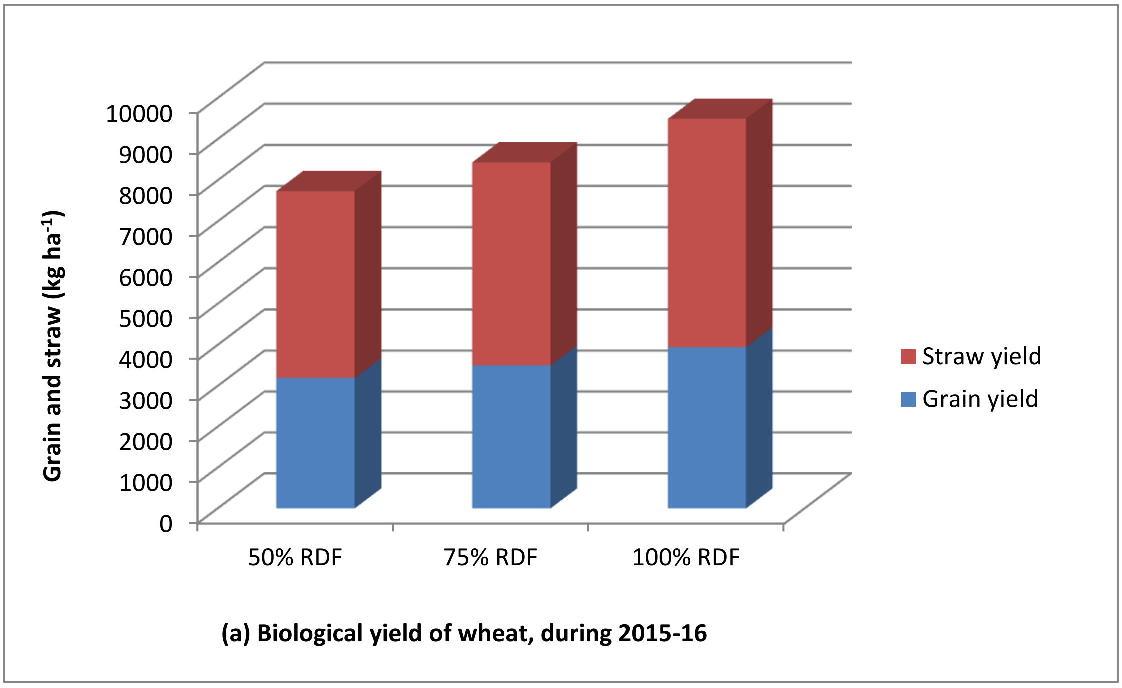
The data on the grain yield, straw yield and harvest index of wheat have been given in (Table 7). Residual effect of treatments applied in maize could not bring about significantly variation in the grain and straw yield and harvest index of wheat during both the years of experimentation.

However, fertilizer levels applied in wheat significantly influenced the grain and straw yield of wheat during both the years. Application of 100% recommended dose of fertilizers (F_3) resulted in significantly highest grain and straw yield of wheat followed by 75% recommended dose of fertilizers (F_2) during both the years of experimentation. The lowest grain and straw yield of wheat was recorded with 50% recommended dose of fertilizers (F_1) during both the years. The harvest index of wheat was not significantly affected due to fertility treatments in wheat. The increase in grain yield due to 100% recommended dose of fertilizers over 75% and 50% recommended dose of fertilizers was 12.65 % and 23.36% during 2015-16 and 7.54% and 22.03% during 2016-17, respectively. The grain yield of wheat is a resultant product of number of spikes per unit area, number of grains per spikes and weight of individual grains[2]. The application of 100% RDF resulted in more ear bearing tillers, more number of grains per ear and weight of 1000-grains in present study, resulting in higher grain yield. Similarly, higher grain yield of wheat with 100% RDF application have also been reported by Dwivedi *et al*.[7] and Kumar[11]. The different fertility levels applied directly to wheat did not influence the harvest index during both the years of investigations. Fertility treatments to wheat brought about significant variation in biological yield (grain+straw) of wheat during both the years (Fig 6). The interaction between nutrient management treatment in maize and wheat could not significantly affect the grain, straw and biological yield and harvest index of wheat during both the years of experimentation.

Table 7. Treatment effects on grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and harvest index (%) of wheat during 2015-16 and 2016-17

Treatment		Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})		Harvest index (%)	
In maize		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
T_1	FYM_{50N} + $Fertilizer_{50N}$	3640	3850	5135	5908	41.48	39.45
T_2	Forti. VC_{50N} + $Fertilizer_{50N}$	3610	3786	5010	5848	41.88	39.30
T_3	VC_{50N} + $Fertilizer_{50N}$	3518	3744	5045	5808	41.08	39.20
T_4	FYM_{25N} + $Fertilizer_{75N}$	3584	3754	5020	5780	41.66	39.37
T_5	Forti. VC_{25N} + $Fertilizer_{75N}$	3532	3688	4970	5654	41.54	39.48
T_6	VC_{25N} + $Fertilizer_{75N}$	3494	3680	4975	5612	41.26	39.60
T_7	RDF	3452	3646	4910	5590	41.28	39.48
SEm±		108	120	126	186	0.48	0.44
CD(P=0.05)		NS	NS	NS	NS	NS	NS
In wheat							
F_1	50% RDF	3197	3340	4541	5235	41.32	38.95
F_2	75% RDF	3501	3790	4935	5805	41.50	39.50
F_3	100% RDF	3944	4076	5552	6189	41.53	39.71
SEm±		72	94	98	162	0.24	0.36
CD(P=0.05)		208	272	283	469	NS	NS

FYM= Farm yard manure, Forti=Fortified, 50N = 50% Nitrogen, VC= Vermicompost,
RDF= Recommended dose of fertilizer



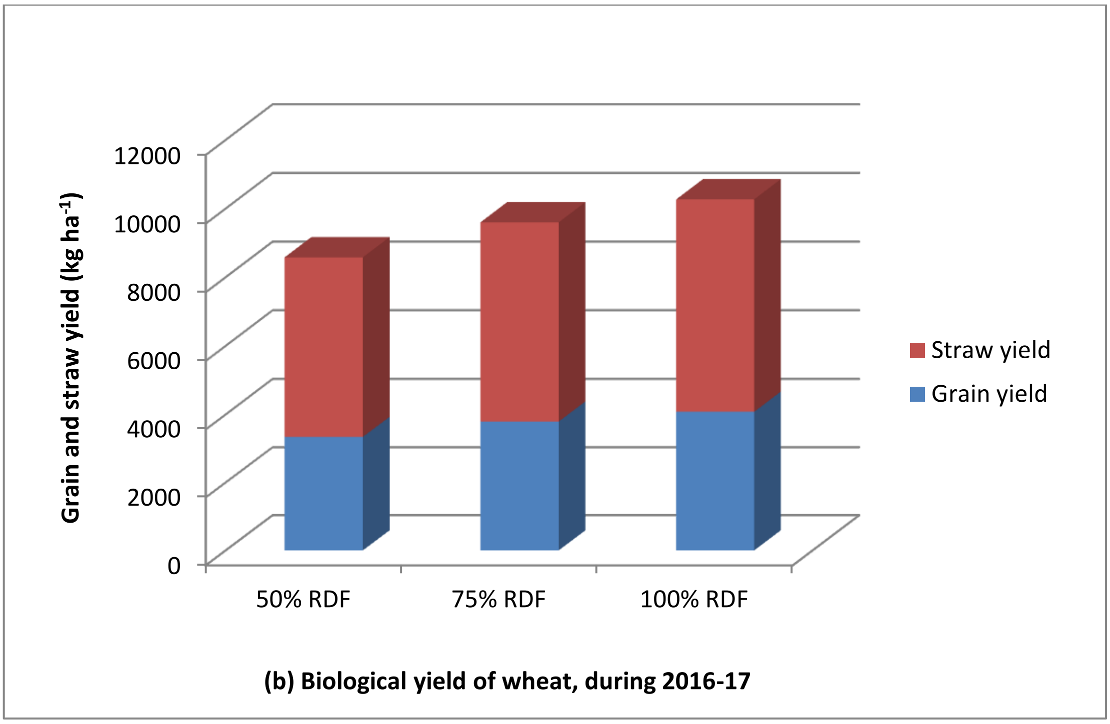


Fig. 6: Treatment effects on biological yield of wheat, (a) 2015-16 and (b) 2016-17

CONCLUSIONS

From this study it may be concluded that, application of 25% of nitrogen either through fortified vermicompost or vermicompost along with nitrogen through inorganic sources of nutrients was found to be as effective as 100% NPK through chemical fertilizers and to enhance the growth and yield attributes of maize. Higher grain and stover yields of maize could be obtained even with substitution of 50% nitrogen either through fortified vermicompost or vermicompost except substitution on by farm yard manure. The residual effect of combined application of organic and inorganic sources of nutrients as well as NPK through chemical fertilizers applied in maize was found to be non-significant in respect of growth, development and yield of succeeding wheat crop.

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