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Impact of Integrated Nutrient Management on Nutrient Content, Nutrient Uptake, Protein Content and Grain Yield in Maize (*Zea mays* L.)-Wheat (*Triticum aestivum* L.) Cropping System in an Acid Alfisol

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ABSTRACT

A field 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, Himachal Pradesh Krishi Vishvavidyalaya, Palampur. Experiment was laid out in randomized block design with three replications comprising seven treatments as applied to maize as main plot i.e. 50% nitrogen through FYM + 50% nitrogen through inorganic fertilizer (T_1); 50% nitrogen through fortified vermicompost + 50% nitrogen through inorganic fertilizer (T_2); 50% nitrogen through vermicompost + 50% nitrogen through inorganic fertilizer (T_3); 25% nitrogen through FYM + 75% nitrogen through inorganic fertilizer (T_4); 25% nitrogen through fortified vermicompost + 75% nitrogen through inorganic fertilizer (T_5); 25% nitrogen through vermicompost + 75% nitrogen through inorganic fertilizer (T_6) and recommended dose of NPK through inorganic fertilizer (T_7); and three treatments to wheat i.e. 50% (recommended dose of NPK through inorganic fertilizers (F_1); 75% RDF (F_2) and 100% RDF (F_3) as sub plots. Higher NPK uptake both in maize and wheat were recorded with combined application of organics and inorganics. Higher content and uptake of nitrogen was observed with 25% N through fortified vermicompost + 75% N through inorganic fertilizer (T_5). However phosphorus and potassium content and uptake was higher in T_7 treatment but being at par with T_5. Residual effect on wheat content and uptake was non significant.

Introduction

Maize (*Zea mays* L.) has become very popular cereal crop in India because of the increasing market price and high production potential of hybrid varieties in both irrigated as well as rainfed conditions. Moreover, in irrigated areas farmers fetch the income equal to the cash crops in comparatively short time period of 120-130 days by cultivating hybrid maize varieties.

The productivity of maize is largely dependent on its nutrient management. It is well known fact that maize is a heavy feeder of nutrients and because of its C_4, nature it is very efficient in converting solar energy into production of dry matter. Globally, maize is known as Miracle crop and "Queen of Cereals" due to high genetic yield potentials than any other cereals counterpart (Kannan *et al.,* 2013). India is the second-most important maize growing country in Asia and world's sixth largest producer and the fifth largest consumer. In India, maize is cultivated in an area of 8.69 million hectares having production of 21.81 million tonnes with a productivity of 2509 kg ha^{-1} (Anonymous 2017). Maize is the major crop of the Himachal Pradesh. The production of maize, which was cultivated on an area 0.30 million hectares having production 0.67 million tonnes with a productivity of 2270 kg ha^{-1} (Anonymous 2017).

Wheat (*Triticum aestivum* L.) is the most important food-grain of India and is the staple food of millions of Indians, particularly in the northern and north-western parts of the country. It is world's second important cereal crop after rice. India is second largest producer of wheat in the world after China with about 12 per cent share in total world wheat production. 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} (Anonymous 2017).

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} (Anonymous 2017). Maize (*Zea mays* L.)-wheat (*Triticum aestivum* L.) both belonging 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. However, the productivity of this existing cropping system in small and marginal farmer's field is very low (Chaudhary and Singh 1992) besides having lower cropping intensity as the fields remain idle for nearly three months.

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 (DeForest *et al.,* 2012). Farmyard manure application to the crop is an age old practice. Well decomposed FYM in addition to supplying of plant nutrients, acts as binding material and improves the soil physical properties. Beneficial effects of earth worms and their cast were known as early as in Darwin's era.

Objectives

1. To study the effect of organic and inorganic sources of nutrients on growth, development and yield of maize,
2. To study the residual effect of organic and inorganic sources on growth, development and yield of wheat,
3. To study the effect of organic and inorganic sources on physical, chemical and biological properties of soil and
4. To study the economics of different treatments

Materials and Methods

Location

The experimental farm is situated at 32^0 6 N latitude and 7603' 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 and 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 2nd 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 (Table 1).

Details of observations recorded

NPK content and uptake in maize and wheat grain and straw

Composite samples of seed and straw taken from each plot at harvest stage of maize and wheat crop were processed and analyzed for total N, P and K content employing standard methods (Jackson, 1973 and Black, 1965).

The N, P, K uptake in maize and wheat after harvest was determined by applying the following formula:

$$\text{Nutrient uptake} = \frac{\text{Nutrient (N/P/K) concentration (\%)}}{\text{Seed/straw yield (kg ha}^{-1}\text{) (N/P/K) (kg ha}^{-1}\text{)}} \text{ X100}$$

Protein content (%) in maize and wheat grains

Protein content of maize and wheat grains from different treatments was estimated by determining nitrogen content by Micro-kjeldahl procedure (Piper 1966). Total N values thus obtained were multiplied with a factor of 6.25 to obtain the protein content.

Grain yield (kg ha^{-1})

The produce from each net plot was harvested and threshed after sun drying. The grains were cleaned and weighed after threshing. The weight of grains recorded on each plot was converted into (kg ha^{-1}) by multiplying with a factor 1453.48.

Straw yield (kg ha^{-1})

Total biological yield (grain + straw) from each net plot was recorded by weighing the sun dried harvested produce. The straw yield was worked out by subtracting the grain yield from biological yield (kg ha^{-1}).

Nutrient content

Data on content of nitrogen, phosphorus and potassium in maize grain and stover have been given in Table 2. The data revealed non-significant differences in the contents of NPK both in grain and stover of maize due to fertility treatments both in maize and wheat. It may be obvious as all treatments in maize are supplied/supplemented 100% NPK through organics or inorganics. The fertilizer supply variation in treatments in wheat also did not cause variation in the content of nutrients in maize grain and stover probably due to exhaustive nature of both the crops. The interaction between nutrient management treatments in maize and wheat also had no significant effect on content of NPK in maize grain and stover.

Nutrient uptake

Data on the uptake of nitrogen, phosphorus and potassium in maize grain, stover and total have been given in Tables 3.1, 3.2 and 3.3, respectively. Nutrient uptake is a function of content and dry matter. In the present study contents did not vary significantly due to fertility treatments in maize and wheat, whatever, variation was therefore, observed, was owed to dry matter production only.

Nitrogen uptake in grain, stover and total

The data in Table 3.1 revealed that variation in N uptake was significantly in grain and stover and thus total uptake by maize crop due to different treatments in maize. Higher uptake of nitrogen in grain, stover and total uptake was recorded in treatment 25% N through fortified vermicompost + 75% N through fertilizer (T_5) which was found at par with recommended dose of fertilizer (T_7) and 25% N through vermicompost + 75% N though fertilizer (T_6) during 2015. However, during 2016 50% N through fortified vermicompost + 50% N through fertilizer (T_2) and 25% N through farm yard manure + 75% N through fertilizer (T_4) also remained at par with former treatments. Since these treatments increased all the growth characters and subsequently resulted in more dry matter yield, more N uptake in grain and stover was obvious compared to rest of the treatments. Although organic manures contain plant nutrients in small quantities as compared to the fertilizer, the presence of growth promoting substances like enzyme and hormones besides supplying plant nutrients make them essential for improvement of soil fertility and productivity. The maintenance of soil physico-chemical and biological properties due to organic and inorganics has been amply supported by Kannan *et al.*, (2013); Choudhary and Kumar (2013) and Sheoran *et al.*, (2015).

The residual effect of fertilizers applied in wheat was not significant on N uptake in grain and stover and thus on total uptake by maize crop. The interaction effect between nutrient management treatments in maize and wheat on nitrogen uptake by maize grain, stover and total was also not significant.

Phosphorus uptake in grain, stover and total (kg ha^{-1})

Data pertaining to phosphorus uptake in maize grain and stover and total given in Table 3.2 revealed that significantly higher uptake of phosphorus in grain, stover and total of maize was recorded in recommended dose of fertilizer (T_7). However, treatments T_2 to T_6 also remained at par with this treatment except T_3 in case of total uptake during both the years of study. The balanced nutrients supply from integrated nutrient sources increased their availability and hence, resulted in more nutrient uptake by the crops. Samaneh *et al.*, (2013) also reported that NPK uptake increased significantly in maize crop by integration of organic and inorganic sources of N.

The residual effect of fertilizers applied in wheat was not significant on P uptake in grain, stover and thus total uptake by maize crop. The interaction effect between nutrient management treatments in maize and wheat on phosphorus uptake by maize grain, stover and total was also not significant.

Potassium uptake in grain, stover and total (kg ha^{-1})

Data on potassium uptake in grains, stover and total uptake given in Table 3.3 showed similar trend of uptake as that for nitrogen and phosphorus uptake.

Significantly higher uptake of potassium in grain, stover and total of maize was recorded in recommended dose of fertilizer (T_7) during both the years. However, this treatment remained 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) during both the years. Uptake was statistically lower in the treatments getting lower doses of organics and chemical fertilizers in both years of observations.

Higher dry matter production resulted in increased uptake of potassium in grains as well as stover. Similar were the observations of Kumar and Dhar (2010) and Manjhi *et al.*, (2014). T_1 (50% N substitution through FYM) had lower numerical values of potassium uptake in grain and stover thus total.

The residual effect of fertilizers applied in wheat was not significant on K uptake in grain, stover and total uptake by maize crop. The interaction effects among nutrient management treatments in maize and wheat on potassium uptake was also not significant.

Protein content

Nutrient management treatments in maize and wheat could not significantly influence protein content in grains of maize during both the years (Table 4). The interaction was also not significant on protein content.

Nutrient content

Data on the content of nitrogen, phosphorus and potassium in grain and straw of wheat have been presented in Table 5.

A perusal of the data revealed that there were no significant differences in the content of NPK both in grain and straw of wheat due to fertility treatments applied both in maize and wheat during both the years.

The fertilizer supply variation of treatments in wheat also did not show significant difference in the contents of nutrients in wheat grain and straw probably due to exhaustive nature of both the crops.

The inverse nitrogen yield relationship may be operative but higher supply of N lead to higher yield and thus not significantly affecting the content. The interaction between nutrient application treatments in maize and wheat also had no effect on content of NPK in wheat grain and straw during both the years.

Nutrient uptake

Data on the uptake of nitrogen, phosphorus and potassium in wheat grain, straw and total have been given in Tables 6.1, 6.2 and 6.3, respectively.

Nitrogen uptake in grain, straw and total

The data in Table 6.1 indicated that organic and inorganic treatments in maize did not significantly influence N uptake in grain and straw and thus total uptake by wheat crop.

Fertility treatments applied in wheat significantly influenced N uptake in grain and straw and thus total by wheat crop. Application of 100% recommended dose of fertilizer (F_3) resulted in significantly higher nitrogen uptake in grain, straw and total followed by 75% and 50% recommended dose of fertilizer during both the years of experimentation. Nutrient uptake is a function of content and dry matter. These results are in conformity with the results obtained by Dwivedi *et al.,* (2014). The interaction effect between nutrient management treatments in maize and wheat on nitrogen uptake by grain, straw and total was also not significant.

Phosphorus uptake in grain, straw and total (kg ha^{-1})

The data on phosphorus uptake by wheat grain and straw and total have been given in Table 6.2. Data revealed non-significant differences among treatments on P uptake in grain and straw and total uptake by wheat crop during both the years.

Fertility treatments applied in wheat had significantly influenced P uptake in grain, straw and thus total uptake by wheat crop. Treatment receiving 100% recommended dose of fertilizers (F_3) resulted in significantly highest P uptake in wheat grain, straw and total compared to 75% and 50% recommended dose of fertilizers.

Significantly lowest P uptake was recorded under 50% recommended doses of fertilizers during both the years. In case of uptake in straw 75% and 100% NPK were at par with each other. Similar results were also reported by Mahala *et al.,* (2006); Shah *et al.,* (2013); and Dwivedi *et al.,* (2014). The interaction effect between nutrient management treatments in maize and wheat was not significant on phosphorus uptake by wheat grain, straw and total during both the years.

Potassium uptake in grain, straw and total (kg ha^{-1})

Data on potassium uptake in grains, straw and total given in Table 6.3 revealed that fertility treatments in maize did not significantly influence potassium uptake in grain, straw and total during both the years of experimentation.

However, treatments applied in wheat had significantly influenced K uptake in grain, straw and thus total by wheat crop. Application of 100% recommended dose of fertilizers (F_3) gave significantly highest potassium uptake in grains, straw and total as compared to 75% and 50% recommended dose of fertilizers. Significantly lowest potassium uptake in wheat grains, straw and total was recorded under 50% recommended dose of fertilizers applied to wheat during both the years. The results of present study confirm the earlier findings of Shah and Wani (2017). The interaction effect between nutrient management treatments in maize and wheat on potassium uptake by wheat grain, straw and total was also not significant.

Protein content (%)

Data on protein content have been given in Table 7. The data revealed that nutrient management treatments in maize and wheat could not influence statistically protein content in grains of wheat during both the year. The interaction between nutrient management treatments in maize and wheat was also not significant on protein content in wheat grains during both the years of investigation.

Grain yield and stover yield

The data on grain and stover yield of maize have been given in Table 8. The combined biological yield (grain and stover) of maize has been depicted in Figure 1.

Grain yield (kg ha^{-1})

An examination of data presented in Table 8. Revealed that 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%. 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 More *et al.,* (2013); Saini and Kumar (2014) and Nasab *et al.,* (2015).

Residual effects of inorganic fertilizer levels applied in wheat were not significant on the grain yield of maize. The interaction between nutrient management treatments in maize and wheat was not significant for grain yield of maize.

Stover yield (kg ha^{-1})

The perusal of data in Table 8 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.,* (2008) and Saini and Kumar (2014) 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.

Biological yield (kg ha^{-1})

Biological yield depicted in Figure 2a and b followed the trend of grain and stover during both years of experimentation. Application of 25% N through fortified vermicompost + 75% N through fertilizer (T_5) and recommended dose of fertilizer (T_7) had higher biological yield during both the years of experimentation. The results of present study confirm the earlier findings of Ravi *et al.,* (2012). Fertility treatments applied in wheat did not have any significant effect on biological yield of maize during both the years.

Grain yield and straw yield

The data on the grain yield, straw yield of wheat have been given in Table 9. Residual effect of treatments applied in maize could not bring about significant 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 spike and weight of individual grains (Arnon 1975). 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 Malghani (2010); Tababtabaei and Ranjbar (2012); Siddiqui *et al.,* (2013); Dwivedi *et al.,* (2014) and Kumar (2015). 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. 2a and b). 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.1 Initial composition of FYM, vermicompost and fortified vermicompost used in the experiment

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

Table.2 Treatment effects on NPK content (%) in maize grain and stover during, 2015 and 2016

Treatment		Nitrogen content (%)				Phosphorus content (%)				Potassium content (%)			
		Grain		Stover		Grain		Stover		Grain		Stover	
In maize		2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
T_1	FYM_{50N} + $Fertilizer_{50N}$	1.15	1.14	0.88	0.48	0.44	0.46	0.08	0.10	0.53	0.54	1.30	1.28
T_2	Forti. VC_{50N} + $Fertilizer_{50N}$	1.16	1.15	0.91	0.46	0.48	0.48	0.09	0.11	0.55	0.54	1.35	1.30
T_3	VC_{50N} + $Fertilizer_{50N}$	1.14	1.14	0.89	0.47	0.46	0.46	0.08	0.10	0.55	0.56	1.33	1.31
T_4	FYM_{25N} + $Fertilizer_{75N}$	1.17	1.16	0.92	0.47	0.47	0.46	0.09	0.09	0.56	0.55	1.33	1.29
T_5	Forti. VC_{25N} + $Fertilizer_{75N}$	1.19	1.16	0.93	0.46	0.47	0.47	0.09	0.10	0.56	0.56	1.37	1.31
T_6	VC_{25N} + $Fertilizer_{75N}$	1.16	1.15	0.92	0.48	0.46	0.47	0.08	0.09	0.57	0.56	1.36	1.31
T_7	RDF	1.17	1.17	0.93	0.44	0.48	0.48	0.10	0.11	0.58	0.57	1.38	1.32
SEm±		0.02	0.02	0.03	0.01	0.02	0.02	0.01	0.01	0.01	0.018	0.02	0.02
CD(P=0.05)		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
In wheat													
F_1	50% RDF	-	1.15	-	0.89	-	0.47	-	0.09	-	0.54	-	1.29
F_2	75% RDF	-	1.15	-	0.88	-	0.46	-	0.10	-	0.56	-	1.31
F_3	100% RDF	-	1.16	-	0.89	-	0.47	-	0.10	-	0.56	-	1.31
SEm±		-	0.01	-	0.01	-	0.01	-	0.01	-	0.01	-	0.01
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

Table.3.1 Treatment effects on nitrogen uptake by grain, stover and total uptake (kg ha^{-1}) in maize during, 2015 and 2016

Treatment		Nitrogen uptake (kg ha^{-1})					
		Grain		Stover		Total	
In maize		2015	2016	2015	2016	2015	2016
T_1	FYM_{50N} + $Fertilizer_{50N}$	41.5	43.5	47.6	49.3	89.1	92.9
T_2	Forti. VC_{50N} + $Fertilizer_{50N}$	44.7	46.6	52.4	53.1	97.1	99.6
T_3	VC_{50N} + $Fertilizer_{50N}$	43.3	43.9	50.2	51.2	93.5	95.1
T_4	FYM_{25N} + $Fertilizer_{75N}$	45.2	47.5	53.0	51.7	98.2	99.2
T_5	Forti. VC_{25N} + $Fertilizer_{75N}$	51.2	50.0	57.9	56.8	109.1	106.8
T_6	VC_{25N} + $Fertilizer_{75N}$	48.6	48.4	56.1	56.2	104.7	104.6
T_7	RDF	50.0.	51.6	58.3	59.4	108.3	111.0
SEm±		1.83	1.66	2.59	2.24	3.66	3.38
CD(P=0.05)		5.65	5.12	7.98	6.90	11.3	10.4
In wheat							
F_1	50% RDF	-	46.4	-	53.3	-	99.8
F_2	75% RDF	-	47.4	-	53.6	-	101.1
F_3	100% RDF	-	48.2	-	55.0	-	103.2
SEm±		-	1.08	-	1.17	-	1.84
CD(P=0.05)		-	NS	-	NS	-	NS

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

Table3.2 Treatment effects on phosphorus uptake by grain, stover and total uptake (kg ha^{-1}) in maize during, 2015 and 2016

Treatment		Phosphorus uptake (kg ha^{-1})					
		Grain		Stover		Total	
In maize		2015	2016	2015	2016	2015	2016
T_1	FYM_{50N} + $Fertilizer_{50N}$	15.9	17.6	4.5	5.7	20.4	21.6
T_2	Forti. VC_{50N} + $Fertilizer_{50N}$	18.5	19.4	5.4	6.6	23.9	25.2
T_3	VC_{50N} + $Fertilizer_{50N}$	17.5	17.7	4.7	5.8	22.2	23.3
T_4	FYM_{25N} + $Fertilizer_{75N}$	18.1	18.8	5.4	5.4	23.5	23.4
T_5	Forti. VC_{25N} + $Fertilizer_{75N}$	20.2	20.2	5.4	6.4	25.6	26.6
T_6	VC_{25N} + $Fertilizer_{75N}$	19.0	19.8	5.1	5.6	24.1	24.7
T_7	RDF	20.7	21.2	6.1	7.2	26.7	27.9
SEm±		1.08	0.89	0.40	0.48	1.35	1.16
CD(P=0.05)		3.31	2.74	1.22	1.46	4.16	3.56
In wheat							
F_1	50% RDF	-	18.97	-	5.39	-	10.8
F_2	75% RDF	-	18.97	-	6.10	-	12.2
F_3	100% RDF	-	19.53	-	6.17	-	12.3
SEm±		-	0.58	-	0.40	-	0.82
CD(P=0.05)		-	NS	-	NS	-	NS

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

Table.3.3 Treatment effects on potassium uptake by grain, stover and total uptake (kg ha^{-1}) in maize during, 2015 and 2016

Treatment		Potassium uptake (kg ha^{-1})					
		Grain		Stover		Total	
In maize		2015	2016	2015	2016	2015	2016
T_1	FYM_{50N} + $Fertilizer_{50N}$	19.3	20.6	70.5	72.6	89.8	93.2
T_2	Forti. VC_{50N} + $Fertilizer_{50N}$	21.3	21.9	78.5	78.4	99.8	100.3
T_3	VC_{50N} + $Fertilizer_{50N}$	21.0	21.6	74.4	76.2	95.4	97.8
T_4	FYM_{25N} + $Fertilizer_{75N}$	21.7	22.5	76.8	76.7	98.5	99.2
T_5	Forti. VC_{25N} + $Fertilizer_{75N}$	24.2	24.1	85.2	83.6	109.4	107.8
T_6	VC_{25N} + $Fertilizer_{75N}$	23.6	23.6	82.4	81.8	106.0	105.4
T_7	RDF	24.9	25.2	86.8	86.1	111.7	111.3
SEm±		0.99	1.18	3.31	2.89	3.80	3.37
CD(P=0.05)		3.06	3.63	10.21	8.91	11.7	10.40
In wheat							
F_1	50% RDF	-	21.8	-	77.3	-	99.1
F_2	75% RDF	-	23.1	-	79.9	-	103.0
F_3	100% RDF	-	23.3	-	80.9	-	104.2
SEm±		-	0.68	-	1.88	-	2.08
CD(P=0.05)		-	NS	-	NS	-	NS

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

Table.4 Treatment effects on protein content (%) in maize grain during, 2015 and 2016

Treatment		Protein content (%)	
In maize		2015	2016
T_1	FYM_{50N} + $Fertilizer_{50N}$	7.17	7.13
T_2	Forti. VC_{50N} + $Fertilizer_{50N}$	7.23	7.19
T_3	VC_{50N} + $Fertilizer_{50N}$	7.15	7.13
T_4	FYM_{25N} + $Fertilizer_{75N}$	7.29	7.25
T_5	Forti. VC_{25N} + $Fertilizer_{75N}$	7.46	7.25
T_6	VC_{25N} + $Fertilizer_{75N}$	7.27	7.19
T_7	RDF	7.31	7.31
SEm±		0.09	0.15
CD(P=0.05)		NS	NS
In wheat			
F_1	50% RDF	-	7.19
F_2	75% RDF	-	7.19
F_3	100% RDF	-	7.25
SEm±		-	0.07
CD(P=0.05)		-	NS

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

Table.5 Treatment effects on NPK content (%) in wheat grain and straw during, 2015-16 and 2016-17

Treatment		**Nitrogen content (%)**				**Phosphorus content (%)**				**Potassium content (%)**			
		Grain		Straw		Grain		Straw		Grain		Straw	
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
T_1	FYM_{50N} + $Fertilizer_{50N}$	1.50	1.43	0.46	0.42	0.330	0.324	0.072	0.073	0.280	0.264	0.71	0.74
T_2	Forti. VC_{50N} + $Fertilizer_{50N}$	1.48	1.45	0.45	0.43	0.340	0.332	0.064	0.070	0.270	0.258	0.73	0.75
T_3	VC_{50N} + $Fertilizer_{50N}$	1.49	1.46	0.45	0.42	0.340	0.323	0.066	0.072	0.270	0.263	0.72	0.74
T_4	FYM_{25N} + $Fertilizer_{75N}$	1.51	1.44	0.47	0.43	0.330	0.314	0.070	0.073	0.290	0.270	0.72	0.73
T_5	Forti. VC_{25N} + $Fertilizer_{75N}$	1.50	1.45	0.46	0.43	0.340	0.324	0.071	0.069	0.270	0.263	0.71	0.74
T_6	VC_{25N} + $Fertilizer_{75N}$	1.49	1.44	0.46	0.42	0.330	0.320	0.069	0.072	0.280	0.268	0.72	0.72
T_7	RDF	1.48	1.46	0.45	0.42	0.330	0.322	0.068	0.069	0.280	0.273	0.73	0.73
SEm±		0.013	0.017	0.016	0.012	0.007	0.011	0.005	0.006	0.010	0.009	0.014	0.016
CD(P=0.05)		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
In wheat													
F_1	50% RDF	1.46	1.42	0.44	0.41	0.320	0.308	0.067	0.070	0.260	0.257	0.70	0.72
F_2	75% RDF	1.50	1.45	0.46	0.43	0.340	0.326	0.070	0.072	0.280	0.267	0.73	0.74
F_3	100% RDF	1.52	1.47	0.47	0.44	0.340	0.334	0.070	0.071	0.290	0.273	0.73	0.75
SEm±		0.022	0.024	0.012	0.010	0.008	0.019	0.004	0.008	0.016	0.016	0.015	0.021
CD(P=0.05)		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

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

Table.6.1 Treatment effects on nitrogen uptake (kg ha^{-1}) in wheat grain, straw and total, during, 2015-16 and 2016-17

Treatment		Grain		Straw		Total	
In maize		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
T_1	FYM_{50N} + $Fertilizer_{50N}$	54.6	55.1	23.6	24.8	78.2	79.9
T_2	Forti. VC_{50N} + $Fertilizer_{50N}$	53.4	54.9	22.6	25.1	76.0	80.0
T_3	VC_{50N} + $Fertilizer_{50N}$	52.4	54.7	22.7	24.4	75.1	79.1
T_4	FYM_{25N} + $Fertilizer_{75N}$	54.1	54.1	24.0.	24.9	77.7	79.0
T_5	Forti. VC_{25N} + $Fertilizer_{75N}$	53.0	53.5	22.9	24.3	75.8	77.8
T_6	VC_{25N} + $Fertilizer_{75N}$	52.1	53.0	23.0	23.6	75.0	76.6
T_7	RDF	51.1	53.2	22.1	23.5	73.2	76.7
SEm±		1.48	1.28	0.72	0.82	1.83	1.69
CD(P=0.05)		NS	NS	NS	NS	NS	NS
In wheat							
F_1	50% RDF	46.7	47.4	20.0	21.5	66.7	68.9
F_2	75% RDF	52.5	55.0	22.7	24.8	75.2	79.8
F_3	100% RDF	60.0	59.9	26.1	27.0	86.0	86.9
SEm±		1.34	1.56	0.57	0.74	1.68	1.94
CD(P=0.05)		3.88	4.5	1.65	2.1	4.9	5.6

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

Table.6.2 Treatment effects on phosphorus uptake (kg ha^{-1}) in wheat grain, straw and total during, 2015-16 and 2016-17

Treatment		Grain		Straw		Total	
In maize		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
T_1	FYM_{50N} + $Fertilizer_{50N}$	12.0	12.47	3.7	4.30	15.7	16.8
T_2	Forti. VC_{50N} + $Fertilizer_{50N}$	12.3	12.57	3.2	4.10	15.5	16.7
T_3	VC_{50N} + $Fertilizer_{50N}$	12.0	12.09	3.3	4.20	15.3	16.3
T_4	FYM_{25N} + $Fertilizer_{75N}$	11.8	11.79	3.5	4.20	15.4	16.0
T_5	Forti. VC_{25N} + $Fertilizer_{75N}$	12.0	11.95	3.5	3.90	15.6	15.9
T_6	VC_{25N} + $Fertilizer_{75N}$	11.5	11.78	3.4	4.00	15.0	15.8
T_7	RDF	11.4	11.74	3.4	3.90	14.7	15.6
SEm±		0.36	0.32	0.22	0.26	0.48	0.52
CD(P=0.05)		NS	NS	NS	NS	NS	NS
In wheat							
F_1	50% RDF	10.2	10.29	3.0	3.70	13.3	14.0
F_2	75% RDF	11.9	12.36	3.5	4.20	15.4	16.6
F_3	100% RDF	13.4	13.61	3.9	4.40	17.3	18.0
SEm±		0.27	0.42	0.18	0.14	0.39	0.46
CD(P=0.05)		0.78	1.22	0.52	0.40	1.13	1.33

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

Table.6.3 Treatment effects on potassium uptake (kg ha^{-1}) in wheat grain, straw and total during 2015-16 and 2016-17

Treatment		Grain		Straw		Total	
In maize		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
T_1	FYM_{50N} + Fertilizer$_{50N}$	12.0	12.47	36.5	43.7	46.7	53.9
T_2	Forti. VC_{50N} + Fertilizer$_{50N}$	12.3	12.57	36.6	43.9	46.3	53.7
T_3	VC_{50N} + Fertilizer$_{50N}$	12.0.	12.09	36.3	43.0	45.8	52.9
T_4	FYM_{25N} + Fertilizer$_{75N}$	11.8	11.79	36.1	42.2	46.5	52.3
T_5	Forti. VC_{25N} + Fertilizer$_{75N}$	12.0	11.95	35.3	41.8	44.8	51.5
T_6	VC_{25N} + Fertilizer$_{75N}$	11.5	11.78	35.8	40.4	45.6	50.3
T_7	RDF	11.4	11.74	35.8	40.8	45.5	50.8
SEm±		0.36	0.32	0.84	1.24	1.02	1.42
CD(P=0.05)		NS	NS	NS	NS	NS	NS
In wheat							
F_1	50% RDF	10.2	10.29	31.8	37.7	40.1	46.3
F_2	75% RDF	11.9	12.36	36.0	43.0	45.8	53.1
F_3	100% RDF	13.4	13.61	40.5	46.4	52.0	57.5
SEm±		0.27	0.42	0.67	0.90	0.98	1.12
CD(P=0.05)		0.78	1.22	1.94	2.6	2.83	3.24

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

Table.7 Treatment effects on protein content (%) in wheat grain during, 2015-16 and 2016-17

Treatment		Protein content (%)	
In maize		2015-16	2016-17
T_1	FYM_{50N} + Fertilizer$_{50N}$	9.38	8.94
T_2	Forti. VC_{50N} + Fertilizer$_{50N}$	9.25	9.06
T_3	VC_{50N} + Fertilizer$_{50N}$	9.31	9.13
T_4	FYM_{25N} + Fertilizer$_{75N}$	9.44	9.00
T_5	Forti. VC_{25N} + Fertilizer$_{75N}$	9.38	9.06
T_6	VC_{25N} + Fertilizer$_{75N}$	9.31	9.00
T_7	RDF	9.25	9.13
SEm±		0.14	0.11
CD(P=0.05)		NS	NS
In wheat			
F_1	50% RDF	9.13	8.88
F_2	75% RDF	9.38	9.06
F_3	100% RDF	9.50	9.19
SEm±		0.24	0.15
CD(P=0.05)		NS	NS

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

Table.8 Treatment effects on grain yield (kg ha^{-1}) and stover yield (kg ha^{-1}) of maize crop during, 2015 and 2016

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

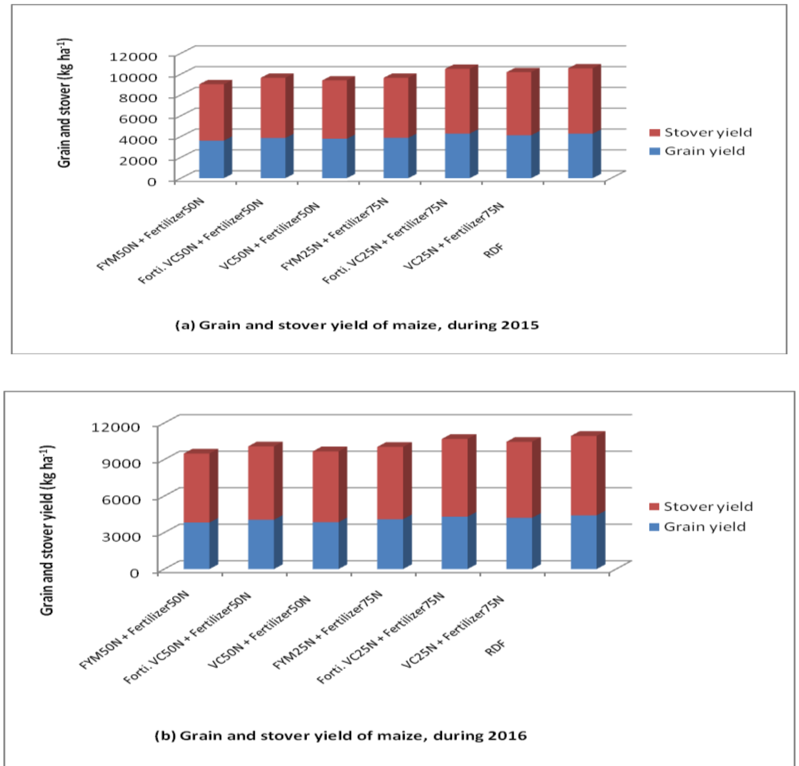
FYM= Farm yard manure, Forti= Fortified, 50N= 50% Nitrogen, VC= Vermicompost, RDF= Recommended dose of fertilizer

Table.9 Treatment effects on grain yield (kg ha^{-1}) and straw yield (kg ha^{-1}) of wheat during, 2015-16 and 2016-17

Treatment		**Grain yield (kg ha^{-1})**		**Straw yield (kg ha^{-1})**	
In maize		2015-16	2016-17	2015-16	2016-17
T_1	FYM_{50N} + $Fertilizer_{50N}$	3640	3850	5135	5908
T_2	Forti. VC_{50N} + $Fertilizer_{50N}$	3610	3786	5010	5848
T_3	VC_{50N} + $Fertilizer_{50N}$	3518	3744	5045	5808
T_4	FYM_{25N} + $Fertilizer_{75N}$	3584	3754	5020	5780
T_5	Forti. VC_{25N} + $Fertilizer_{75N}$	3532	3688	4970	5654
T_6	VC_{25N} + $Fertilizer_{75N}$	3494	3680	4975	5612
T_7	RDF	3452	3646	4910	5590
SEm±		108	120	126	186
CD(P=0.05)		NS	NS	NS	NS
In wheat					
F_1	50% RDF	3197	3340	4541	5235
F_2	75% RDF	3501	3790	4935	5805
F_3	100% RDF	3944	4076	5552	6189
SEm±		72	94	98	162
CD(P=0.05)		208	272	283	469

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

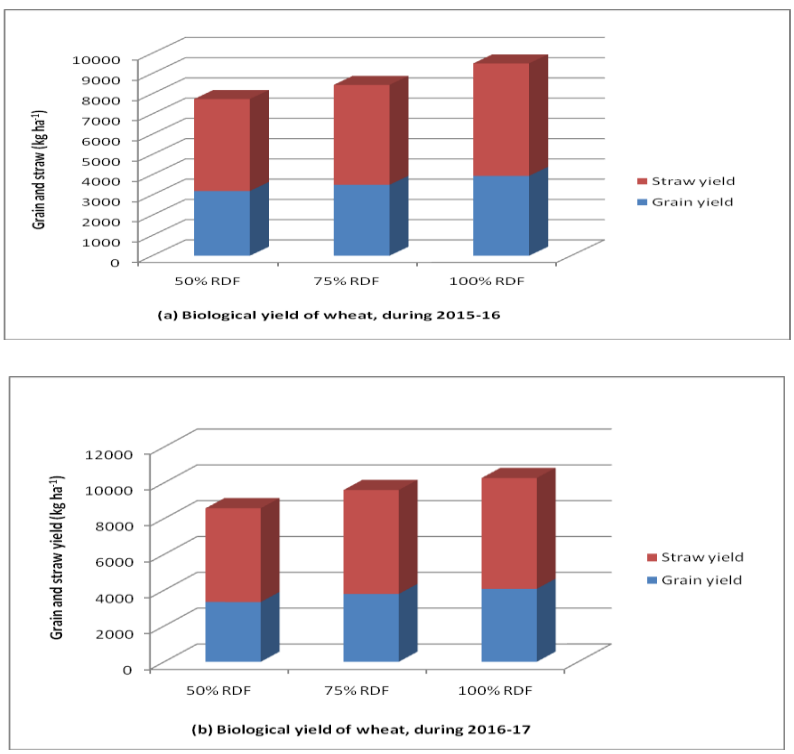
Fig.1 Treatment effects on biological yield of maize, (a) 2015 and (b) 2016



(a) Grain and stover yield of maize, during 2015

(b) Grain and stover yield of maize, during 2016

Fig.2 Treatment effects on biological yield of wheat, (a) 2015-16 and (b) 2016-17



(a) Biological yield of wheat, during 2015-16

(b) Biological yield of wheat, during 2016-17

Conclusion

- Nutrient management treatments in maize and fertilizer treatments to wheat have not influenced contents of NPK as well as protein content both in grain and stover of maize.
- Higher uptake of NPK in grain, stover and total of maize was recorded with 25% N through fortified vermicompost + 75% N through fertilizer (T_5) remaining at par with 25% N through vermicompost + 75% N through fertilizer (T_6) and recommended dose of fertilizers (T_7)
- NPK content as well as protein content in grain and straw of wheat were not affected by the fertilizer levels applied to wheat during both the years. However NPK uptake by grain and straw of wheat was significantly higher in the 100% recommended dose of fertilizer compared to 75% and 50% recommended dose of fertilizer during both years.
- Application of 25% of nitrogen either through fortified vermicompost or vermicompost along with 75% nitrogen through inorganic fertilizer was found to be as effective as 100% NPK through chemical fertilizers enhancing 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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