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RESPONSE OF FIELD GROWN HYBRID MAIZE TO INTEGRATED USE OF INORGANIC AND ORGANIC POTASSIUM FERTILIZERS

G. S. Mastoi[1], Zia-ul-hassan, I. Rajpar, A. N. Shah and S. A. Qureshi[2]

[1]Department of Soil Sciences, Sindh Agriculture University, Tandojam, Pakistan
[2]Agriculture Research Sindh, Tandojam, Pakistan

ABSTRACT

In Pakistan, farming community avoid using potassium (K) fertilizers due to their high cost which results in big yields gaps. This field study was conducted to evaluate the response of hybrid maize to integrated use of inorganic and organic K fertilizers. The experiment was conducted in a randomized complete block design (RCBD) with six treatments and three repeats by growing hybrid maize (32F10) at six varying levels of K, i.e. 00-00 (control), 30-00, 00-30, 30-30, 60-00, 00-60 kg K ha^{-1}, supplied through inorganic and/or organic K fertilizer, respectively. The soil under study was heavy in texture, alkaline in nature, free from salinity hazards, low in organic matter and deficient in AB-DTPA extractable K. Potassium application @ 60 kg ha^{-1}, either organic or inorganic, was superior to 30 kg ha^{-1} in boosting various growth traits of maize crop. The integrated use of K was more effective than single use of K and saved 50% of the chemical K fertilizer. Potassium nutrition enhanced various traits of maize, viz. plant height (2 to 15%), fresh biomass (13 to 60%), cob yield (16to 76%), grain yield (22 to 83%), 1000 grain weight (2 to 30%), and K concentration (150 to 366%). The K accumulation was highly significantly correlated with all the growth traits and explained the enhancement in grain yield under integrated K nutrition. The study concluded that K application at 60 kg ha^{-1}, by integrating organic and inorganic K fertilizers @ 30 kg ha^{-1} each, potentially improved the growth and biomass production of maize. Further research is warranted to validate these results.

Keywords: Maize, organic fertilizer, potassium, yield.

INTRODUCTION

Maize (*Zea mays* L.) is an important cereal crop of world. In Pakistan, maize crop occupies an area of 1052.1 ‘000’ ha with a total production of 3593.0 ‘000’ tons and an average yield of 3415 kg ha^{-1}. The average yield of maize in Pakistan is far below than that obtained by her neighbor China (5556 kg ha^{-1}) or when compared to the global average yield of maize (5109 kg ha^{-1}) (GoP, 2010). According to the plant nutritionists, the rapid mining of potassium (K) from

Corresponding author: zhnshah@gmail.com

Pakistani soils could be the main culprit for such crop yield stagnant situations that may even result into reduction of crop yield (Zia-ul-hassan *et al*., 2011). The recent studies report K mining from 43% Pakistani soils, including the most important benchmark soil series of Pakistan (Zia-ul-hassan *et al*., 2008). Potassium is considered as the most important essential major plant nutrient due to its cascade of roles in plant physiology and biochemistry (Nawaz *et al*., 2006; Zia-ul-hassan *et al*., 2011). Apart from its important roles in plant physiology and biochemistry, K has also been considered as the major yield and quality contributing nutrient in maize production (Bukhsh *et al*., 2012). The involvement of K in maize nutrition ensures optimum yield and quality (White, 2003; Bukhsh *et al*., 2012). Nawaz *et al*. (2006) reported high K requirement of 15 maize genotypes of Pakistan. These researchers noted severe reduction in shoot and root biomass of all the maize genotypes under K deficiency stress. On the other hand, adequate K nutrition increased biomass accumulation of all the maize genotypes under study. The K use efficient genotypes had higher root biomass under K deficient condition which suggested that these genotypes were able to explore K from larger volumes. The positive effects of K on maize growth, yield and quality parameters are now well established in the literature (Bukhsh *et al*., 2012). The growth and yield components of maize like leaf area (Meille and Pellerin, 2008), crop growth rate, plant height, number of grains cob^{-1}, cob length, 1000-grain weight, grain and biological yield are significantly increased by K application (Pettigrew, 2008; Bukhsh *et al*., 2012). In line to these positive effects of K nutrition on maize growth and yield parameters, the quality traits of maize grains such as crude protein content (Usherwood, 1985), crude starch content (Mahmood *et al*., 2000) and crude oil content (Ali *et al*., 2004) also improved by adequate amounts of K application to maize crop. The maximum (almost 2/3) K absorption and accumulation occurred at flowering stage in maize (Shangwen *et al*., 2009). The K uptake of maize is very rapid and it can go beyond 05 kg K ha^{-1} daily during first 07 weeks of sowing (White, 2003), while the above ground parts of a mature maize crop can accumulate 300 kg K ha^{-1} (Karlen, 1988). The assimilation and accumulation of K by K-efficient maize genotypes are always higher than their inefficient counterparts (Shangwen *et al*., 2009). Hence, it is understood that in the absence of adequate K nutrition optimum yield and quality of a maize crop can't be achieved. However, in view of the scorching prices of K fertilizers in Pakistan, the plant nutritionists must search alternate sources of K nutrition of crops. Pakistan has been facing the problem of ever increasing amounts of solid waste. These organic wastes successfully supplement plant nutrition, improve soil health and environmental quality and reduce input cost of chemical fertilizers, if they are effectively composted (Arshad *et al*., 2007; Ahmad *et al*., 2008a). These composted organic wastes are enriched with nutrients, e.g. nitrogen (N), phosphorus (P) and potassium K and/or blended with plant growth regulators, such as auxin precursor L-tryptophan, to make various types of organic fertilizer products (Arshad *et al*., 2007). The soil application of such organic fertilizers at substantially lower rates (≤300 kg ha^{-1}), supplemented with only a quarter to half of the recommended dose of chemical fertilizers, enhances crop yields, quality, nutrient uptake and soil health (Arshad *et al*., 2004; Ahmad *et al*., 2006a, b; Tahir *et al*., 2006; Arshad *et al*., 2007; Ahmad *et al*., 2008a,b). Despite these encouraging results, the technology of developing low-cost, nutrient enriched, organic fertilizers is only limited to the formulation of nitrogen enriched organic fertilizers which were also successfully used to benefit the nutrition of various crops.

However, no any study is reported in relation to the development of organic K fertilizer to support inorganic K nutrition of crops in quest of sustainable crop production and environmental promotion. This study was proposed to test the response of field grown maize to a newly developed organic potassium fertilizer in integration with chemical potassium fertilizer. The specific objectives of this field study were to evaluate the growth and yield of field grown hybrid maize to integrated use of inorganic and potassium fertilizers and to determine the relationship of maize grain yield with K accumulation.

MATERIALS AND METHODS

The experiment was conducted at the Latif Experimental Farm, Sindh Agriculture University Tandojam, Pakistan, in a randomized complete block design (RCBD) with six treatments repeated thrice. The experiment involved growing of hybrid maize (32F10) under varying levels of K, i.e. 00-00 (control), 30-00, 00-30, 30-30, 60-00, 00-60 kg K ha^{-1}, applied through inorganic and/or organic K fertilizer, respectively. The size of each experimental unit was 4m x 6 m= 24 m^2. The crop received recommended doses of nitrogen (150 kg ha^{-1}) and phosphorus (75 kg ha^{-1}). Nitrogen (N) was supplied as urea (46% N) while phosphorus was given as (diammonium phosphate, DAP (18% N and 46% P_2O_5). The source used for inorganic K nutrition was SOP (potassium sulphate). The organic K fertilizer was developed from fruits and vegetables' wastes as described by Arshad *et al*. (2007). All the phosphorus and potassium, along with half dose of nitrogen, was supplied to the crop by broadcasting to the soil and then thoroughly mixed. The remaining half dose of nitrogen was given to the crop at first irrigation. The required doses of organic K fertilizer, i.e. 30 and 60 kg K ha^{-1} were developed by enriching 300 kg organic compost and 10 mg L-Trytophan kg^{-1} of composted material for application at a piece of one hectare. The amount of K already contributed by organic material was kept in mind for calculation. The soil under study was analyzed for some physico-chemical properties and K content by taking composite sample before hybrid maize sowing, following the methods prescribed by Ryan *et al*. (2001). The chemical analyses revealed that the soil of experimental area was heavy in texture (41% clay), alkaline in nature (pH: 7.9), free from salinity hazards (EC: 1.2 dS m^{-1}). Moreover, the soil was poorly fertile and found low in organic matter (0.52%) and AB-DTPA extractable potassium (121 mg kg^{-1}). The crop was irrigated according its requirements by following the recent recommendations. All the other recommended agronomic and cultural practices were also followed throughout the life span of the crop. At maturity, the five plants were harvested from each experimental unit to observe their plant height (cm), fresh biomass (g $plant^{-1}$), cob yield (g $plant^{-1}$), grain yield (g $plant^{-1}$) and 1000 grain weight (g). The collected data was subjected to requisite statistical analyses using Statistaxver. 8.1. The analysis was done by following randomized complete block design. The treatment means were separated at alpha 0.05.

RESULTS AND DISCUSSION

Plant height (cm)

The mean square from analysis of variance (603.5) reflected that different K treatments significantly ($p < 0.001$) affected the plant height of maize (Table 1). Involving K in maize nutrition increased its plant height. Higher K application rate (60 kg ha^{-1}) was significantly more superior to the lower application rate (30 kg ha^{-1}), irrespective of their source. Furthermore, inorganic K nutrition increased plant height more significantly over organic K nutrition, at the same level of K (Fig. 1). Applying 30 kg K ha^{-1} increased plant height and this increase was more in case of inorganic K nutrition (247.5) as against organic K nutrition (244.2 cm). Where K was applied @ 60 kg ha^{-1}, the maximum plant height (238.7 cm) was obtained through inorganic K nutrition, followed by the treatment receiving K nutrition (263.5 cm) through organic K fertilizer alone and integrated K nutrition (261.0 cm) (Fig. 1). Application of 30 kg K ha^{-1} through inorganic and organic K fertilizers increased plant height up to 3% and 2%, respectively, over control (no K application). Similarly, as compared to control, application of 60 kg K ha^{-1} through inorganic and organic K nutrition increased plant height up to 15% and 10%, respectively. Moreover, K application @ 60 kg ha^{-1}, by integrating both K sources, increased plant height of maize up to 9% (Fig. 1).

Table 1. Significance of mean squares from analysis of variance of various parameters of maize in relation to integrated use of potassium.

Parameter	Mean square for K treatments
Plant height	603.49***
Fresh biomass	24754.0***
Cob yield	14034.0***
Grain yield	10049.5***
1000- grain weight	6754.2***
K concentration	5.33***

Note: *, ** and *** represent significance levels at alpha 0.05, 0.01, and 0.001.

Fresh biomass (g plant^{-1})

The mean square from analysis of variance (24754) illustrated that different K treatments significantly ($p < 0.001$) influenced fresh biomass of maize (Table 1). The involvement of K in maize nutrition increased its fresh biomass (Fig. 1). Similar to plant height of maize, higher K application rate (60 kg ha^{-1}) was significantly more superior to the lower application rate (30 kg ha^{-1}), irrespective of their source. Moreover, organic K nutrition increased fresh biomass more significantly over inorganic K nutrition, irrespective of K application rates (Fig. 1). Minimum fresh biomass of maize (373.5 g) was obtained where no K was applied (control) (Fig.1). Applying 30 kg K ha^{-1} increased fresh biomass and this increase was more in case of organic K nutrition (484.1 g) as against inorganic K nutrition (422.6 g) (Fig. 1). Where K was applied @ 60 kg ha^{-1}, the maximum fresh biomass (599.1 g) was obtained through integrated K nutrition, followed by the treatment receiving inorganic K nutrition (568.4 g) and through the single application of organic K fertilizer (566.5 g) (Fig. 1). Application of 30 kg K ha^{-1} through inorganic and organic K fertilizers increased fresh biomass up to 13% and 29%, respectively, over control (no K application). Similarly, as compared to control, application of 60 kg K ha^{-1} through inorganic and organic K nutrition increased fresh biomass up to 52% and 51%, respectively. Moreover, fresh biomass of maize increased up to 60% by the integrated application of 60 kg K ha^{-1} (Fig. 1).

Cob yield (g $plant^{-1}$)

The mean square from analysis of variance (14034.0) illustrated that different K treatments significantly ($p < 0.001$) influenced cob yield of maize (Table 1). The involvement of K in maize nutrition increased its cob yield (Fig. 1). Similar to other parameters, higher K application rate (60 kg ha^{-1}) was significantly more superior to the lower application rate (30 kg ha^{-1}), irrespective of their source. Moreover, organic K nutrition increased cob yield more significantly over inorganic K nutrition, irrespective of K application rate (Fig. 1). Minimum cob yield of maize (215.1 g) was obtained where no K was applied (control) (Fig. 1). Applying 30 kg K ha^{-1} increased cob yield and this increase was more in case of organic K nutrition (269.5 g) as against inorganic K nutrition (250.8) (Figure 1). Where K was applied @ 60 kg ha^{-1}, the maximum cob yield (378.6) was obtained through integrated K nutrition, followed by the treatment receiving organic K nutrition (364.2) and through organic K fertilizer alone (351.7) (Fig. 1). Application of 30 kg K ha^{-1} through inorganic and organic K fertilizers increased cob yield up to 16% and 25%, respectively, over control (no K application). Similarly, as compared to control, application of 60 kg K ha^{-1} through inorganic and organic K nutrition increased cob yield up to 63% and 69%, respectively. Moreover, cob yield of maize increased up to 76% by the integrated application of 60 kg K ha^{-1} (Fig. 1).

1000 grain weight (g)

The mean square from analysis of variance (6754.2) illustrated that different K treatments significantly ($p < 0.001$) influenced 1000 grain weight of maize (Table 1). The involvement of K in maize nutrition increased its 1000 grain weight (Fig. 1). Similar to other parameters, higher K application rate (60 kg ha^{-1}) was significantly more superior to the lower application rate (30 kg ha^{-1}), irrespective of their source. Moreover, inorganic K nutrition increased 1000 grain weight more significantly over organic K nutrition, irrespective of K application rate (Figure 1). Minimum 1000 grain weight of maize (326.7) was obtained where no K was applied (control) (Fig. 1). Applying 30 kg K ha^{-1} increased 1000 grain weight and this increase was more in case of organic K nutrition (356.7 g) as against inorganic K nutrition (333.7 g) (Fig. 1). Where K was applied @ 60 kg ha^{-1}, the maximum 1000 grain weight (426.7) was obtained through inorganic K nutrition, followed by the treatment receiving integrated K nutrition (424.1) and through organic K fertilizer alone (420.2) (Fig. 1). Application of 30 kg K ha^{-1} through inorganic and organic K fertilizers increased 1000 grain weight up to 2% and 9%, respectively, over control (no K application). Similarly, as compared to control, application of 60 kg K ha^{-1} through inorganic and organic K nutrition increased 1000 grain weight up to 30% and 28%, respectively. Moreover, 1000 grain weight of maize increased up to 29% by the integrated application of 60 kg K ha^{-1} (Fig. 1).

Grain yield (g $plant^{-1}$)

The mean square from analysis of variance (10049.5) illustrated that different K treatments significantly ($p < 0.001$) influenced grain yield of maize (Table 1). The involvement of K in maize nutrition increased its grain yield (Fig. 1). Similar to other parameters, higher K application rate (60 kg ha^{-1}) was significantly more superior to the lower application rate (30 kg ha^{-1}), irrespective of their source. Moreover, inorganic K nutrition increased grain yield more significantly over organic K nutrition, irrespective of K application rate (Fig. 1). Minimum grain yield of maize (163.6 g) was obtained where no K was applied (control) (Fig. 1). Applying 30 kg K ha^{-1} increased grain yield and this increase was more in case of organic K nutrition (203.0 g) as against inorganic K nutrition (200.4) (Fig. 1). Where K was applied @ 60 kg ha^{-1}, the maximum grain yield (300.8) was obtained through integrated K nutrition, followed by the treatment receiving inorganic K nutrition (289.3) and through organic K fertilizer alone (282.8) (Fig. 1). Application of 30 kg K ha^{-1} through inorganic and organic K fertilizers increased grain yield up to 22% and 24%, respectively, over control (no K application). Similarly, as compared to control, application of 60 kg K ha^{-1} through inorganic and organic K nutrition increased grain yield up to 76% and 72%, respectively. Moreover, grain yield of maize increased up to 83% by the integrated application of 60 kg K ha^{-1} (Fig. 1).

Potassium concentration (%)

The mean square from analysis of variance (5.3) illustrated that different K treatments significantly ($p < 0.001$) influenced K concentration of maize (Table 1). The involvement of K in maize nutrition increased its K concentration (Fig. 1). As noted in case of plant height, higher K application rate (60 kg ha^{-1}) was significantly more superior to the lower application rate (30 kg ha^{-1}), irrespective of their source. Moreover, inorganic K nutrition increased K concentration more significantly over organic K nutrition, irrespective of K application rates (Fig. 1). Minimum K concentration of maize (1.0%) was obtained where no K was applied (control) (Fig. 1). Applying 30 kg K ha^{-1} increased K concentration and this increase was more in case of inorganic K nutrition (2.6%) as against organic K nutrition (2.4%) (Fig. 1). Where K was applied @ 60 kg ha^{-1}, the maximum K concentration (4.90%) was obtained through integrated K nutrition, followed by the treatment receiving inorganic K nutrition (3.90%) and through organic K fertilizer alone (3.40%) (Fig. 1). Application of 30 kg K ha^{-1} through inorganic and organic K fertilizers increased K concentration up to 1.5-fold and 1.3-fold, respectively, over control (no K application). Similarly, as compared to control, application of 60 kg K ha^{-1} through inorganic and organic K nutrition increased K concentration up to 2.7-

fold and 2.2-fold, respectively. Moreover, K concentration of maize increased up to 3.6-fold by the integrated application of 60 kg K ha^{-1} (Fig. 1).

Relationship of grain yield with K accumulation of maize in relation to integrated use of potassium

The relationships among K concentration, grain yield and biomass production of maize determined through correlation analysis (Table 2) explain that K nutrition of maize significantly ($p < 0.05$ to < 0.001) enhanced the K accumulation of plants and hence increased their growth traits which consequently improved the grain yield and biomass production of maize. The present study endorsed the beneficial effects of potassium (K) in maize nutrition. Inclusion of K in maize nutrition significantly improved grain yield, K accumulation and biomass production of maize (Table 1, Fig. 1). The data (Fig. 1) depict that the K nutrition improved various traits of maize, viz. Plant height (up to 15%), fresh biomass (up to 60%), cob yield (up to 76%), grain yield (up to 83%), 1000 grain weight (up to 30%) and K concentration (up to 3.6-fold). The correlation analysis (Table 2) explained that the K nutrition of maize significantly ($p < 0.001$) enhanced K accumulation of maize and hence improved all the growth traits of maize which consequently improved the grain yield and biomass production of maize.The results of the present study are in-line with many studies conducted in recent past highlighting the positive effects of K on maize growth, yield and quality parameters (Nawaz *et al*., 2006; Bukhsh *et al*., 2012). Some other studies also reported that K nutrition improves the growth and yield components of maize like leaf area (Meille and Pellerin, 2008), crop growth rate, plant height, number of grain cob^{-1}, cob length, 1000-grain weight, grain and biological yield (Pettigrew, 2008; Bukhsh *et al*., 2012).

Table 2. Relationship among different growth traits, potassium concentration and biomass production of maize in relation to integrated use of potassium.

Parameter	Plant height	Fresh biomass	Cob yield	Grain yield	1000 grain weight
Fresh biomass	0.843*	-	-	-	-
Cob yield	0.865*	0.985***	-	-	-
Grain yield	0.907*	0.974**	0.992***	-	-
1000 grain weight	0.912*	0.971**	0.982***	0.981***	-
K concentration	0,794*	0.932**	0.929**	0.943**	0.878*

Note:*, ** and *** represent significance levels at alpha 0.05, 0.01 and 0.001, respectively. ‘NS’ denotes non-significance.

Similarly, the quality traits of maize grains such as crude protein content (Usherwood, 1985), crude starch content (Mahmood *et al*., 2000) and crude oil content (Ali *et al*., 2004) were also improved by adequate K application. In this study, the integrated use of inorganic and organic K fertilizers at 60 kg ha^{-1} enhanced maize grain yield, growth and biomass production significantly superior to other K treatments, i.e. single use of K either at 30 or 60 kg ha^{-1} (Fig. 1).

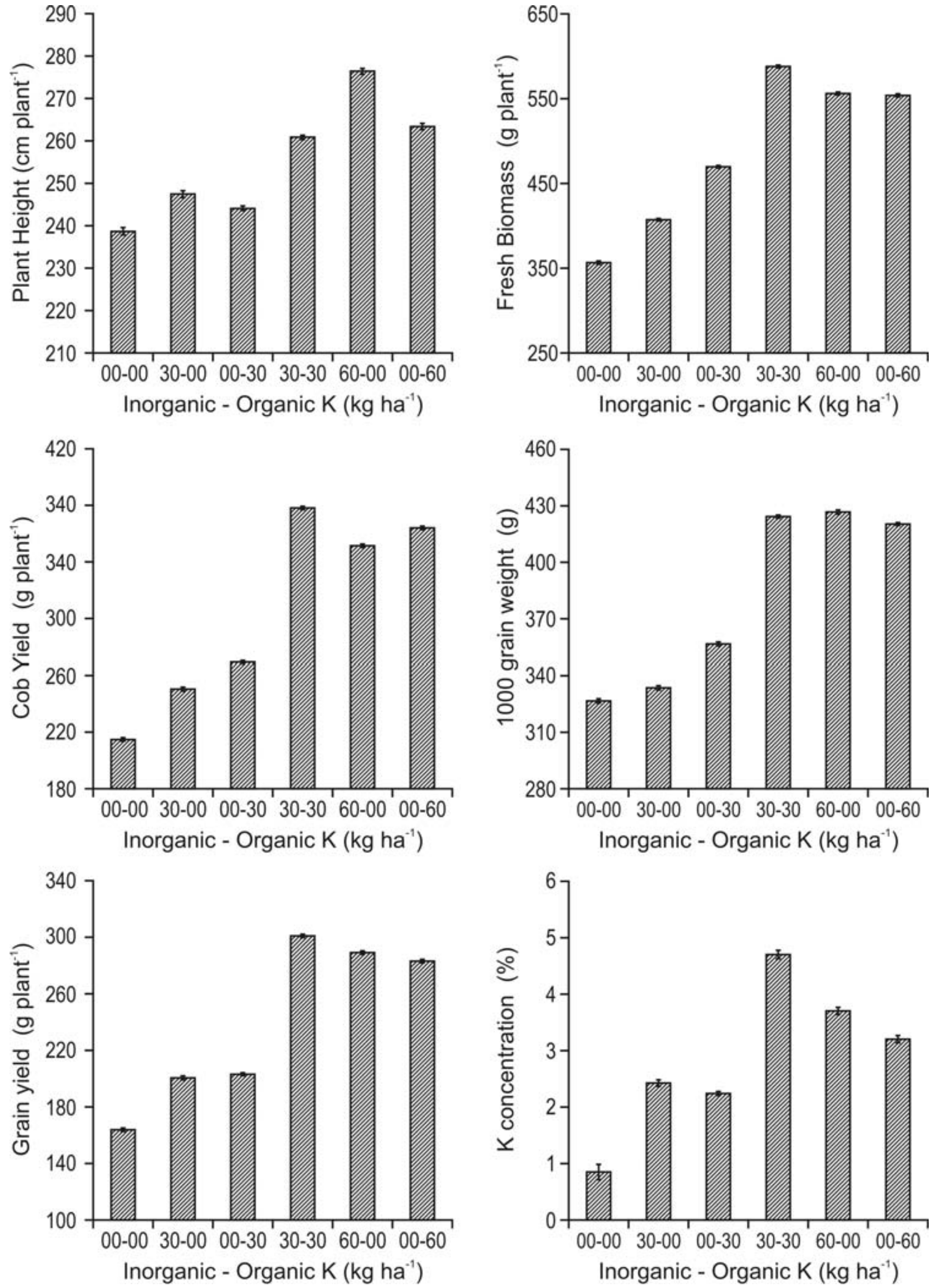

Fig. 1. Plant height, fresh biomass and cob yield, 1000-grain weight, grain yield and K concentration of maize in relation to potassium application through inorganic and organic fertilizers at varying levels.

Earlier too, it has been reported by various research workers that the soil application of nutrient-enriched organic fertilizers at substantially lower rates, supplemented with only a quarter to half of the recommended dose of chemical fertilizers, enhances crop yields, quality, nutrient uptake and soil health (Arshad *et al*., 2004; Ahmad *et al*., 2006a,b; Tahir *et al*., 2006; Arshad *et al*., 2007; Ahmad *et al*., 2008a,b). Ahmad *et al*. (2006a) conducted pot and field experiments to compare the effectiveness of raw and composted fruit and vegetable wastes for improving growth and yield of maize. The results clearly demonstrated the superiority of N-enriched composted organic material over the raw organic waste supplemented with N fertilizer and caused significant improvement in growth, yield and nutrient uptakes of maize. Similar results were obtained by Tahir *et al*. (2006) in terms of improved growth, fruit yield and N concentration of tomato in response to organic fertilization. Later on, Zahir *et al*. (2007a) found that application of N and L-TRP-enriched compost @ 500 kg ha^{-1} was as effective as full dose of N fertilizer in improving growth and yield of wheat, saving 30% N fertilizer. Ahmad *et al*. (2007b) elucidated that the application of nitrogen and L-tryptophan enriched compost significantly promoted growth, yield and nutrient content of wheat and maize. Ahmad *et al*. (2008a) observed that the nitrogen enriched compost blended with or without IAA/GA3 supplemented with half dose of N fertilizer was as effective as full dose of N fertilizer in improving growth and yield of maize as well as wheat, saving ~ 25% N fertilizer. These results open new vistas of research and development in the organic nutrition of crops for sustainable agriculture in the era of high cost of chemical fertilizers and ever increasing environmental pollution. These nutrient-enriched, value-added composted organic fertilizers not only save fertilizer demand of crops but also improves the growth and yield of crops.

CONCLUSION

The study concluded that K application at 60 kg ha^{-1}, by integrating 30 kg ha^{-1}chemical K fertilizer with 30 kg ha^{-1}organic K fertilizer, developed from fruits and vegetables organic waste material, improved the growth, biomass production, grain yield and K accumulation of maize.

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