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Integrated Use of Recycled Organic Waste and Chemical Fertilizers for Improving Maize Yield

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ABSTRACT

A wire house experiment was conducted to study the integrated effect of un-composted, composted (recycled) organic waste and inorganic fertilizer on maize crop. One forth (44 kg ha^{-1}) of recommended level of N fertilizer (175 kg ha^{-1}) for maize was applied after blending in fruit and vegetable wastes during composting and same rate was applied along with un-composted organic waste. Phosphorus and potassium fertilizers were kept constant as control in all treatments. Compost enriched with 25% N (EC) was further supplemented with 25 and 50% recommended rate of N and compared with recommended N fertilizer. Both treatments significantly improved all yield parameters over control, integrated use of EC and 50% N, however, was statistically at par with chemical fertilizers in improving growth and yield parameters of maize. The study indicated that EC plus 50% N fertilizer resulted in saving of ~25% chemical N fertilizer. Results also revealed that 25% N in composted form was superior in improving growth and yield of maize to 25% N applied directly to soil along with un-composted organic waste. Findings of the trial suggest that efficiency of N fertilizer may significantly improve, when it is blended in composted organic waste providing more nutrients for longer time. At the same time it also depicts that un-composted material may cause immobilization of applied N fertilizer, which reduces its efficiency. Hence instead of using chemical fertilizer alone, its integrated use along with composted organic materials could be more effective, economical and sustainable for both agriculture and environment.

Key Words: Organic waste; Composting; N fertilizer; Maize yield

INTRODUCTION

Organic wastes are considered as a rich source of macro and micronutrients (Shah & Anwar, 2003). In Punjab only, compostable material from urban wastes is estimated to be three million tons per annum. Its plant nutrient potential is equivalent to 20, 500, 3300 and 17800 tons of N, P and K, respectively beside large quantities of micronutrients (Qayaum, 2001). With the advent of chemical fertilizers, the use of organic wastes as plant nutrient source was restricted. It is continuous stress on national economy, as rich pool of nutrients contained by organic wastes is being lost and at the same time potential threat for sustainability of environment.

Many strategies are being adopted to dispose off organic wastes but none of them is safer for environment and sustainable for nutrient conservation. Direct application of organic waste as such into the field has many draw backs as un-composted organic materials have wider C: N ratio than composted organic material, this causes immobilization of applied N and hence N becomes un-available to plant. Finished compost is generally more superior to un-composted materials having more concentrated of nutrients, narrower in C: N ratio and also being effectively free from pathogens, weed seeds and other potential contaminants that cause pollution (Zia *et al*., 2003).

Composting is one of the best solutions to reduce the huge piles of organic wastes and convert it in to a value added product. It is one of the major recycling processes by which nutrients present in organic materials are returned back to the soil in plant available form (Inckel *et al*., 1996). Composting is controlled decomposition and appropriate stabilization of blended organic substrates under aerobic condition that allow the development of thermophilic temperature as a result of biologically produced heat.

Sole use of chemical fertilizers is causing deterioration in soil physical, chemical and biological properties. The inadequate and imbalance use of chemical fertilizers is resulting in stagnant even low crop yields in Pakistan as compared to other developed countries. High cost and un-availability of fertilizer at the time of application further aggravates the economic condition of farmers. The integrated use of organic and inorganic plant nutrient sources not only recycles organic waste causing environmental pollution but also conserves rich pool of nutrients resources, which can reduce the sole dependence on chemical fertilizers.

The integrated use of organic nutrient sources with inorganic fertilizer was shown to increase the potential of organic fertilizer (Heluf, 2002) and to improve the efficiency of inorganic fertilizer. So their use could be reduced up to certain levels. Incorporation of chemical fertilizers in composted materials improves its efficiency and reduces losses (Guar & Geeta, 1993). Keeping all above in view the present study was focused on recycling organic waste in to value added product for sustainable agriculture and environment.

MATERIALS AND METHODS

Preparation of enriched compost. Fruit and vegetable wastes were collected from local fruit and vegetable market and juice shops of Faisalabad city. Collected material was made free from un-wanted materials (pieces of glass, stones, polythene bags etc.), which cannot be recycled. This sorted waste material was sun dried for couple of days and then passed through a crusher to extract excessive moisture/juice. After air drying the material was oven dried at $55 \pm 5^{o}C$ for 24 h depending upon the nature of the material. The oven dried waste material was ground in to finer particles with the help of an electric grinder. The ground material was transferred to a composter and water was added @ 30 L 100 kg^{-1} compost after determining the moisture percentage of ground material. During composting, the material was converted in to an effective organic fertilizer by blending with 25% recommended rate of N (Urea) for maize crop and incubating at suitable aeration and temperature for six days with constant stirring. After composting, dark brown colored stable product was obtained which was packed in gunny bags till use. Both ground raw and finished composted material was analyzed for their nutrient contents (Table I) before application in the pot.

Pot trial. The effectiveness of 25% N enriched compost was compared with un-composted ground material plus 25% N. Recommended rate of N fertilizer and un-treated control (PK) were also kept for comparison in pot trial. Pot trial was conducted in wire house of Institute of Soil and Environmental Sciences, University of Agriculture Faisalabad. Soil was collected, air dried, sieved and analyzed for physico-chemical characteristics before filling the pots. The soil was sandy clay loam having pH, 7.7; EC, 2 dS m^{-1}; Organic matter, 0.65%; total nitrogen, 0.04%; available phosphorus, 8.8 mg kg^{-1}; and extractable potassium 126 mg kg^{-1} soil. NPK fertilizers were applied @ 175 – 100 - 50 kg ha^{-1} as urea, SSP, SOP, respectively. Fertilizers (P & K) were mixed in each pot (containing12 kg soil), at the time of pot filling before sowing as basal dose. Enriched compost and un-composted ground material were also applied @ 300 kg ha^{-1} at the time of pot filling, where required. N was applied in two splits after germination and before tassling according to treatment plan given below.

T1: Untreated control (0 N)
T2: Recommended N fertilizer
T3: Un-composted material + 25% N fertilizer
T4: Enriched compost (containing 25% N fertilizer)
T5: Enriched compost + 25% N fertilizer
T6: Enriched compost + 50% N fertilizer.

Hybrid maize (hybrid maize corn 786) was sown with four replications. Initially four seeds were sown pot^{-1}, after germination, thinning was done and one plant pot^{-1} was maintained. Canal water having suitable criteria was used for irrigation. Data regarding plant height, fresh biomass, fresh cob weight, fresh root weight, 1000-grain weight and grain yield were recorded at maturity. Grain and shoot samples of maize plants were analyzed for N contents and their total up-take in maize plants were determined. Data was analyzed statistically using completely randomized design (Steel & Torrie, 1980). Means were compared by Duncan's Multiple Range test (Duncan, 1955).

RESULTS

Results of pot trial revealed that maximum plant height (22% higher than control) was recorded, where recommended chemical fertilizer (NPK) was applied (Table I). Compost blended with 25% N (EC) plus 50% N in chemical form was statistically at par with recommended N producing 19% more than control. EC + 25% N, was significant to control producing 16% more plant height. Un-composted ground material + 25%N differed significantly from 25% N in composted form. Later showed 12% increase as compared to 6% by former over control.

Results of fresh root weight (FRW) in pot trial (Table I) indicated that recommended N fertilizer and EC + 50% N were non-significant with each other producing 88.4 and 78.8% more FRW than control. Compost containing 25% N in blended form was significant (57.6%) to 25% N along with un-composted ground material (34.6%), however supplementation of the former with 25% chemical fertilizer (N), statistically produced similar result (65% over control).

Data regarding 1000-grain weight of pot trial (Table I) showed that all treatments differed significantly from each others. Maximum 1000-grain weight was shown by recommended chemical fertilizer (57.8%), followed by EC + 50% N (52.8), EC + 25% N (42.8), EC alone (36.4) and un-composted material + 25% N, 28.5% over control, respectively.

Data regarding fresh biomass of pot trial (Table II) demonstrated that all treatments differed significantly from each other. Recommended N fertilizer gave maximum fresh biomass (52.9%), followed by EC + 50% N and EC plus 25% N, producing 46.6 and 35% more biomass over control, respectively. Enriched compost alone produced 25.8% more than control as compared to 17.5% by 25% N in combination with un-composted ground material.

Maximum fresh cob weight was again recorded by recommended N fertilizer, 77.7% over control (Table II). It was followed by 63.3 and 41.1% increase by EC + 50% N and EC + 25% N. Compost enriched with 25% N produced double (22.2%) than 25% N along with un-composted organic material (11.1%).

Grain yield of pot trial (Table II) revealed that 50% recommended N + EC and recommended N fertilizer produced statistically similar grain yield 51.1 and 57.1% over control. EC supplemented with 25% N produced 42.8% more than control. EC alone and un-composted material + 25% N were significant with each other and to control as well producing 31.4 and 18.5% more grain yield.

Table I. Nutrient composition

Parameter[A]	Ground Material (Uncomposted)	Finished Compost
C (%)	31.25	18
N (%)	1.25	1.8[B]
C/N ratio	25	10
P (%)	0.18	0.24
K (%)	1.20	1.50
Moisture (%)	13	15

[A]Carbon contents and macronutrients were determined according to the methods described by Nelson and Sommers (1996), Ryan et al. (2001).
[B]Nitrogen concentration in the enriched compost was 12%.

Table II. Effect of un-composted material, enriched compost and chemical fertilizer on plant height, fresh root weight and 1000-grain yield of maize crop (average of four repeats)

Treatment*	Plant height (cm)	Fresh root weight (g plant^{-1})	1000-grain weight (g)
Control (0 N)	100 e	52 d	140 f
Recommended N fertilizer	122 a	98 a	221 a
Un-composted material + 25% N	106 d	70 c	180 e
Enriched Compost (EC)	112 c	82 b	191 d
Enriched Compost + 25% N	116 b	86 b	200 c
Enriched Compost + 50% N	119 ab	93 a	214 b

*Recommended doses of P and K were applied to all treatments including control; Values sharing similar letters do not differ significantly at $p<0.05$, according to Duncan' multiple rang test

Table III. Effect of un-composted material, enriched compost and chemical fertilizer on fresh biomass, fresh cob weight and grain yield of maize crop (average of four repeats)

Treatment*	Fresh biomass (g plant^{-1})	Fresh cob weight (g plant^{-1})	Grain yield (g plant^{-1})
Control (0N)	240 f	90 f	70 e
Recommended N fertilizer	367 a	160 a	110 a
Un-composted material+25%N	282 e	100 e	83 d
Enriched Compost (EC)	302 d	110 d	92 c
Enriched Compost +25% N	324 c	127 c	100 b
Enriched Compost +50% N	352 b	147 b	106 a

*Recommended doses of P and K were applied to all treatments including control; Values sharing similar letters do not differ significantly at $p<0.05$, according to Duncan' multiple range test

Full dose of N fertilizer or EC in integration with 50% N showed maximum increase (132.5 & 125% over control) in N contents of maize grain (Table IV). EC in combination with 25% N increased N contents of grain up to 101.25% over control. Both un-composted material along with 25% N and composted 25% N significantly increased N contents of maize grain but composted one was better than un-composted showing 75 vs. 56.25% increase over control.

Regarding straw, maximum N% was obtained by full dose of recommended N or half along with EC that ranged from 191.6 to 212.5% over control (Table IV). It was followed by EC plus 25% N (150% more than control). Compost enriched with 25% N increased N content of straw up to 116% compared to un-composted plus 25% N (83% over control) and both were non-significant with each other.

Data of total N up-take in Table IV demonstrated that recommended N or 50% N along with EC showed maximum increase (256 to 270%) over control. EC plus 25% N also showed significant increase (174%) over control. One fourth of recommended N along with un-composted and composted material, differed significantly from each other regarding total up-take of N in maize, showing 94 and 138% increase over control, respectively.

Table IV. Effect of un-composted material, enriched compost and chemical fertilizer on N% in grain and straw and total uptake of N in maize crop (average of four repeats)

Treatment*	N % in Grain	N % in straw	Total uptake of N (g pot^{-1})
Control (0N)	0.80 e	0.24 e	0.50 e
Recommended N fertilizer	1.86 a	0.75 a	1.85 a
Un-composted material+25%N	1.25 d	0.44 d	0.97 d
Enriched Compost (EC)	1.40 c	0.52 c	1.19 c
Enriched Compost +25% N	1.61 b	0.60 b	1.37 b
Enriched Compost +50% N	1.80 a	0.70 a	1.78 a

*Recommended doses of P and K were applied to all treatments including control; Values sharing similar letters do not differ significantly at $p<0.05$, according to Duncan' multiple rang test

DISCUSSION

Results of pot trial revealed the effectiveness of integration of organic and inorganic resources of plant nutrients. EC + 50% N significantly improved plant height, fresh biomass, fresh cob weight, fresh root weight, 1000-grain weight and grain yield over control. Statistically it was at par with recommended N fertilizer saving~25% N fertilizer. These findings are supported by many researchers; Satyanarayana *et al.* (2002) found maximum grain yield of rice with application of FYM@10 t ha^{-1} and inorganic fertilizer@120: 60: 45 kg N: P_2O_5: K_2O ha^{-1}. Jadhav *et al.* (2000) evaluated the integrated use of organic manures and fertilizer on the growth and yield of sugarcane and found saving of 25% N fertilizer dose through application of FYM. Similarly, Jayanthi *et al.* (2002) found that application of 50% recommended NPK + (Vermicompost + FYM each at 5 t ha^{-1}) recorded higher green fodder yield of oat (40.5 t ha^{-1}), which was comparable with that of 100% recommended NPK fertilizer. However, the novelty of our approach was that organic material was applied @ 300 Kg ha^{-1} as organic fertilizer using composting and N blending technology, while others used in tones per hectare as a source of organic matter.

It was found that EC + 50% N and recommended N fertilizer produced almost similar grain yield in pot trial. On the whole it was concluded that blending 25% N in compost and integrating with 50% N fertilizer had the potential to substitute 100% N fertilizer in chemical form reducing its use up to 25%. It is likely that N losses due to leaching, denitrification or volatilization might have reduced due to blending of N fertilizer with compost resulting in improved N use efficiency and long term release of nutrients from compost. This premise is supported by the fact of N contents in straw and grain and total N up-take by maize plants (Table I).

Results also revealed that there was significant increase in plant height, fresh biomass, fresh cob weight, fresh root weight, 1000-grain weight and grain yield by 25% N enriched compost vs. un-composted organic material plus 25% recommended N. Composted material with narrow C: N ratio and 25% N blended in it was more effective than un-composted plus 25% N. As un-composted organic material had wider C: N ratio might have caused immobilization of applied N. This finding is strengthened by the fact of N contents in straw and grain and total N up-take by maize plants (Table IV). These results are also supported by Fujiwara (1987), who reported that totally decomposed compost increased fresh weight of spinach by 11% and dry weight by 5%, whereas partially decomposed compost was less effective and even decreased the fresh weight by 33% and dry weight by 32% compared with control. Similar explanation is given by Loecke *et al*. (2004), who reported that composted manure increased corn grain yield more than fresh manure (10.3 vs. 8.8 Mg ha^{-1}). They also found that fresh manure decreased corn emergence by 9.5% compared with un-amended, control treatment.

Economic analysis. Raw organic waste is available free of cost in huge amounts and there is no demand-supply gap expected as application rate of 300 kg ha^{-1} is feasible and economical for the farmers to apply. The novelty of the approach being used in this study was the application of EC just at the rate of 300 kg ha^{-1}, as previously effect of raw/compost organic material was studied by applying tones ha^{-1} by many researchers (Nevens & Reheul, 2003; Wolkowski, 2003). This rate can be applied along with fertilizers without any extra cost, while storage, transportation, handling and application of organic waste in tones ha^{-1} is un-economical. Moreover, composting is economical and safe mean of organic wastes management than other approaches being used like land filling, burning etc. The technology is, therefore cost effective economically as to collect and manage waste is the duty of Government, farmers have to just apply after municipalities have done the rest work. The reduction in the use of chemical fertilizer and huge piling of organic waste are economical benefits of this technology.

CONCLUSION

The integrated nutrient supply and management through judicious use of organic and chemical means will lead to sustainable and high crop production. There is an urgent need for adopting integrated nutrient supply system for promoting the efficient and balance use of macro and micronutrients for plants. While main emphasis has to be on increasing use of chemical fertilizer in the right and balanced amount, the role of the organic manure and recycled organic wastes has to be supplementary rather than substitutive. It is, therefore, possible to shift the plateau to a higher level with complementary use of organic with chemical fertilizer than chemical fertilizers alone. The complementary use of various sources of nutrients is helpful in improving fertilizer use efficiency, conserving nutrients, maintaining soil productivity and health and recycling nutrients from organic wastes.

The recycling of organic wastes and its development into a value added product through blending/enriching with certain nutrients and plant growth regulators could not only help in achieving high productivity in agriculture but also in maintaining sustainable environment.

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REFERENCES

Duncan, D.B., 1955. Multiple range and multiple F-test. *Biometrics,* 11: 1–42

Fujiwara, S., 1987. Decomposition of Poultry Manure Compost Mixed with Sawdust and Effects of its Application on Crop Growth. *In:* Dynamics of organic matter in Paddy soil jointly held by IRRI-National Institute of Agricultural Environment, Ministry of Japan

Guar, A.C. and Geeta, 1993. *Role of Integrated Plant Nutrient Systems in Sustainable and Environmentally Sound Agricultural Development*: Pp: 110–30. RAPA Publication: 1993/13, FAO, Bangkok

Heluf, G., 2002. *Soil and water Management Research Program Summary Report of 2000/2001 Research Activities*, P: 95. Alemaya Research Center, Alemaya University

Inckel, M.P. de Smet, T. Tersmette and T. Veldkamp, 1996. *The Preparation and Use of Compost Fourth Edition*. P: 28. Trans. E.W.M. Verheij. Wagenningen, the Netherlands

Jadhav, B.S., R.D. Nigade and U.A. Kadam, 2000. Integrated management of organic manures and fertilizers in seasonal sugarcane. *J. Maharashtra Agric. University India,* 25: 274–6

Jayanthi, C., P. Malarvizhi, A.K. Fazullah and C. Chinnusamy, 2002. Integrated nutrient management in forage oat (Avena sativa). *Indian J. Agron*., 47: 130–3

Loecke, T.D., M. Liebman, C.A. Cambardella and T.L. Richard, 2004. Corn response to composting and time of application of solid swine manure. *Agron. J.,* 96: 214–23

Nevens, F. and D. Reheul, 2003. The application of vegetable, fruit and garden waste (VFG) compost in addition to cattle slurry in a silage maize monoculture: nitrogen availability and use. *European J. Agron.,* 19: 189–203

Qayyum, F., 2001. *Disposal of City Waste*. Daily Dawn 13 Aug. 2001

Satyanarayana, V., P.V.V. Prasad, V.R.K. Murthy and K.J. Boote, 2002. Influence of integrated use of farmyard manure and inorganic fertilizers on yield and yield components of irrigated lowland rice. *Indian J. Pl. Nutrition,* 25: 2081–90

Shah, Z. and M. Anwar, 2003. Assessment of solid waste for nutrient elements and heavy toxic metals. *Pakistan J. Soil Sci*., 22: 1–10

Steel, R.G.D. and J.H. Torrie, 1980. *Principles and Procedures of Statistics. A Biomaterical Approach,* 2nd Ed. McGraw Hill, Inc. Book Co. New York, USA

Wolkowski, R.P., 2003. Nitrogen management considerations for land spreading municipal solid waste compost. *J. Environ. Quality*, 32: 1844–50

Zia, M.S., S. Khalil, M. Aslam and F. Hussain, 2003. Preparation of compost and its use for crop-production. *Sci. Technol. Develop.,* 22: 32–44

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