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INTEGRATED USE OF FARM MANURE AND MINERAL FERTILIZERS TO MAINTAIN SOIL QUALITY FOR BETTER COTTON (*Gossypium hirsutum* L.) PRODUCTION

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A field experiment was conducted on cotton crop to evaluate the effect of farm manure (FM) alone and in combination with the mineral fertilizers. FM was treated with the 1% application of effective microorganism prepared with molasses to enrich the status of FM as FM-Fermented. Cotton Varity Krishma was cultivated in field with treatments viz. control, FM @ 20Mg ha^{-1}, FM-Fermented@ 20 Mg ha^{-1}, ½ NPK+FM (20 Mg ha^{-1}), ½ NPK+ FM-Fermented (20 Mg ha^{-1}) and NPK (175-85-60 kg ha^{-1}). The experiment was laid out according to randomized complete block design with four replications. At flowering stage fully expanded younger leaves were collocated and analysed for N, P and K contents. Growth and yield parameters of cotton like plant height, sympodial branches, no. of boll $plant^{-1}$, seed cotton boll $plant^{-1}$ and seed cotton yield kg ha^{-1} were recorded. Soil was analyzed after the harvest of crop for N, P, K and organic matter contents. Data were analysed statistically. The results of the experiment indicated that application of recommended dose of NPK produced higher seed cotton yield (2660 kg ha^{-1}) and followed by ½ NPK+FM-Fermented (2523 kg ha^{-1}) and differed significantly from other treatments. There was positive increase in the N, P and K concentration in cotton leaves and in soil due to the combined application of ½ NPK+FM-Fermented.
Keywords: Farm manure, FM-Fermented, mineral fertilizers, NPK contents, cotton

INTRODUCTION

The fertility of soil is a very dynamic concept which can be readily influenced by climatic variations and cultural practices (Ayoub, 1999). Now-a-days, mineral fertilizers have become a necessary factor in the maintenance of soil fertility. However, the massive use of these fertilizers and limitations in cultivation practices such as burning the stubbles have greatly reduced the content of organic matter in soils, which directly influencing the physical, chemical and biological properties of soils (Tejada *et al*., 2003).
Mineral fertilizers have some distinctive feature over farm manures in readily supplying the nutrients in soil, principally nitrogen, phosphorus and potassium alone or in combination. The purpose of fertilizer applications is to enhance soil fertility and crop production (FAO, 1998). The resultantly enhanced plant productivity are associated with greater returns of organic materials in the form of decaying root, litter and crop residues , which helped to rise soil organic C levels. The inorganic fertilizers have significant impact on food production in the whole world, and are highly required component of today's agriculture. Estimates showed that about 50% increase in agricultural production is brought about through the addition of these fertilizers (FAO, 1998) and 60% of humanity is depending on nitrogenous fertilizers to overcome their nutritional demands (Fixon and West, 2002).
The information on the impact of long term use of NPK in soil organic C content is inconsistent, probably due to influences of cropping pattern, soil and environmental factors. In reliance to such situations, there is a strong effort worldwide to adopt green manures, legumes and organic materials to generate same quantity of food as with the utilization of inorganic fertilizers. In general, there is a considerable move towards low input sustainable agriculture (Prasad, 1998; Ram and Kumar, 1996). There are numerous research publications reporting the efficiency and effectiveness of farm manure and other organic nutrient resources in improving soil fertility, crop yields and sustaining productivity particularly when integrated with mineral fertilizers (Asfaw *et al*., 1997; Heluf *et al*., 1999). The microbial inoculations help to maintain the fertility of soil but are effective under specific environments for a specific crop. The best alternate is the use of organic residues and manures in combination with inorganic fertilizers, which can help to reduce the cost of production by providing nutrition on one hand and improving soil health and its properties on the other. These organic resources are required in abundance but their role in improving soil properties and enhancing fertilizer use efficiency when

applied in combination with mineral fertilizers is enormous (Caravaca *et al*., 2002; Haq *et al*., 2002; Martinez *et al*., 2003; Abbasi *et al*., 2003).

The integrated use of organic manures, mineral fertilizer and bio-fertilizers helps to sustain yield, and build up soil quality for better production (Nasir *et al*., 2012). The addition of effective microorganism in organic manures is as an added dimension to improve the nutrient status. These microorganisms help to decompose organic manures to conserve carbon and synthesize nitrogen (Sangakkara and Higa, 1992) through the process of mineralization. These microorganisms are photosynthetic bacteria, lactic acid bacteria, actinomycetes and ray fungi. These microorganisms help to decompose the organic manures through the process of fermentation (Higa and Kinjo, 1991). This process of decompositions helps the slow release of nutrients and maintains the energy losses. The numerous research workers tested the efficiency of these effective microorganisms on crops and concluded the positive interaction towards the yield and nutrient concentrations. Among these, the research work by Higa and Wididan (1991), Parr *et al*. (1994), Daly *et al*. (1999), Zia *et al.* (1999a,b), Haq *et al.* (2002), Vliet *et al*. (2006) and Khaliq *et al*. (2006) showed the effectiveness of these microorganism and concluded that the yield of crop obtained was almost comparable with the mineral fertilizers. These microorganisms also improved the soil productivity and the nutrient cycling (Paschoal *et al*., 1995; Tokeshi *et al*., 1996).

Keeping in view the importance of organic matter (manure), mineral fertilizer and the role of effective microorganism to enhance the nutrient status of soil, a comprehensive study was planned to cultivate cotton with the objectives to sustain soil quality with the addition of farm manure treated with effective microorganism to get maximum cotton yield.

MATERIALS AND METHODS

A field experiment was conducted at the experimental area of Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan. Soil was sandy clay loam having pH 7.74, ECe 1.23 dSm^{-1}; water retention capacity 33.1%, Total N 0.025%, Available P 8.45 mg kg^{-1}, K 110.1 mg $kg^{-1}$and OM 0.47% This soil was classified as Typic Camborthoid with Hafizabad series (Soil Survey Sta 1999).Cotton variety Krishma was cultivated according to randomized complete block design (RCBD) with four replications. The treatments were control, FM @ 20 Mg ha^{-1}, FM -Fermented @ 20 Mg ha^{-1}, ½ NPK + FM (20 Mg ha^{-1}), ½ NPK +FM- Fermented (20 Mg ha^{-1}), NPK (170-85-60 Kg ha^{-1}). The temperature during growth perid was in the range of 29°C to 40°C.

In the laboratory, Farm Manure (having N 1.54 %, P 0.46%, K 1.53%, Organic matter 85.7% and C: N 32.9%) was treated with the inoculums 1% solution of effective microorganisms. FM was taken in plastic bags @ 5 kg bag^{-1} and treated with 1% solution of Effective Microorganisms with the respective control (Haq *et al*., 2002; Sena *et al*., 2002). Incubation was carried out for 15 days. After the completion of incubation, FM was analyzed for N, P, K, organic matter, organic C, C:N ratio and named as FM-***Fermented***: It contains 1.97% N, 0.63 % P, 2.09% K, 54.4 % OM and 19.9 C/N ratios. This FM–Fermented and Farm manure (FM) was applied @ 20 Mg ha^{-1} in the field before the cultivation of cotton crops in each year. On the basis of analysis this quantity of FM -Fermented was equivalent to 98 kg N, 33 kg P, 107.5 kg K on per hectare basis and FM (Control) contains 75.5 kg N, 21 kg P and 73 kg K ha^{-1}.

***Experimental layout*:** Plot size was 7×5 m, cotton plants were sown with plant to plant distance of 30 cm and row to row distance of 45 cm. Farm manure and FM- Fermented was appiled 15 days before the sowing of cotton crop and mineral fertlizer was aplied according to the treatments in the soil. Urea, DAP, K_2SO_4 were used as source of NPK. Phosphrous and potassium were applied at the time of sowing while N was applied in three split doses,1st at the time of sowing, 2nd at 1st irrigation and 3rd at flowering. The cotton was irrigated with canal irrigation (4 irrigations each of 2"). At maturity, plant height (cm), sympodial branches, no.of bolls $plant^{-1}$,seed cotton $boll^{-1}$ and seed cotton yield kg ha^{-1} were recorded.

***Ionic analysis*:** At flowering stage , fully expanded younger leaves were collected ,washed with distilled watrer, air dried and than oven dried at 65°C. Then leave samples were ground and stored for the analysis of total N (Jackson, 1962), P (Olsen, 1982) and K (U.S. Salinity Lab., 1954). The soil samples were collected at the harvest of cotton crop (0-20cm depth) and analysed for N,P,K and OM contents (Johnston , 1986).

***Statistical analysis*:** The data collected for various parameters were analysed statistically by "Analysis of Variance Techniques (Fisher, 1925). The treatment mean were compared by Duncan Multiple Range test (Duncan, 1954) at 5% probability level.

RESULTS

***Growth parameters of cotton crop*:** Data regarding growth parameters are presented in Table 1. The statistical interpretation of the data indicated that all the treatments have significant impact on the different growth parameters. The maximum plant height (110 cm), sympodial branches (22), boll $plant^{-1}$ (38), seed cotton $boll^{-1}$ in grams (4.2) and seed cotton yield kg ha^{-1} (2660) was observed , where recommended dose of mineral fertilizer, i.e. NPK was applied, , followed by half dose of NPK along with FM-Fermented (fermented farm manure with the inoculation of effective microorganisms). The trend in growth parameters

Table 1. Effect of Farm manure and mineral fertilizers on growth parameters of cotton crop.

Treatments	Plant height (cm)	Sympodial branches plant^{-1}	No. of bolls plant $^{-1}$	Seed cotton boll^{-1} (g)	Seed cotton yield (kg ha^{-1})	% increase in yield over control
Control	96 e	13 e	25 c	3.7 d	1459 e	-
FM @ 20 Mg ha^{-1}	101 cd	17 d	30 b	3.7 d	1857 cd	27
FM-Fermented@ 20 Mg ha^{-1}	100 d	18 c	32 b	3.8 cd	1749 d	19
½ NPK + FM (20 Mg ha^{-1})	103 c	18 c	32 b	3.9 bc	1974 c	35
½ NPK+FM-Fermented (20 Mg ha^{-1})	108 b	20 b	37 a	4.1 ab	2523 b	72
NPK (175-85-60 kg ha^{-1})	110 a	22 a	38 a	4.2 a	2660 a	82

Means followed by same letter(s) are statistically non significant at $P \leq 0.05$;
Each value is an average of four replications.

was NPK > ½ NPK + FM-Fermented> ½ NPK + FM > FM-Fermented > FM > Control.

There was 82 % increase in seed cotton yield in NPK (recommended) followed by ½ NPK +FM-Fermented (72 %) over the control. Maximum plant height sympodial branches, number of bolls per plant, seed cotton per boll and seed cotton yield kg per hacters with the application of recommended dose of NPK, is might be due to the rapid release of the nutrients which were readily taken up by the plants, and is resulted in increase in the plant growth and yield contributing factors.

Nutrient concentration in cotton leaves**:** The data regarding nutrient concentration (NPK) in cotton leaves are presented in Table 2. There was significant impact of treatments on nutritional concentration in leaves especially N, P, K. The maximum N (2.3%) P (0.28%) K(2.4%) was recorded where we applied recommended dose of mineral fertilizer followed by 1/2NPK + FM fermented manure i.e., 2.2, 0.25 and 2.2 percent NPK respectively in cotton leaves. The regression equations were also drawn to determine the relationship of NPK with grain yield of cotton. There was positive correlation especially the integration of half NPK with fermented farm manure. The coefficient of determination curves (Fig.1, 2 and 3) represents the co-efficient of determination. It was (r^2) 0.95 in case of N, 0.83 for P and 0.93 for K.

Table 2. Nutrients concentration in cotton leaves

Treatments	N (%)	P (%)	K (%)
Control	1.7d	0.21b	1.5b
FM@ 20 Mg ha^{-1}	1.9cd	0.23ab	1.6b
FM-Fermented @ 20 Mg ha^{-1}	1.9c	0.24ab	1.7b
½ NPK + FM (20 Mg ha^{-1})	2.0bc	0.24ab	1.8b
½ NPK + FM-Fermented (20Mg ha^{-1})	2.2ab	0.25ab	2.2a
NPK (175-85-60 kg ha^{-1})	2.3a	0.28a	2.4a

Means followed by same letter are statistically non significant at $P \leq 0.05$; Each value is an average of four replications

Nutrient concentration in soil after cotton harvest: Data regarding nutrient concentration in soil are presented in Table 3. Results of the experiment indicated that the nutrients like N, P and K, and organic matter were affected by the treatments. Maximum concentration of NPK and organic matter were achieved in the treatment, where recommended dose of NPK were applied and differ significantly from the other treatments and control. This increase was might be due to rapid decomposition of organic products in soil due to application of mineral fertilizers.

Table 3. Nutrient concentration in soil after cotton harvest

Treatments	N (%)	P (mg kg^{-1})	K (mg kg^{-1})	OM (%)
Control	0.03 a	6.62 d	81 d	0.44 e
FM@ 20 Mg ha^{-1}	0.04 a	8.18 cd	90 cd	0.49 d
FM-Fermented @ 20 Mg ha^{-1}	0.04 a	7.38 c	97 cd	0.58 c
½ NPK + FM (20 Mg ha^{-1})	0.05 a	7.65 bc	107 bc	0.64 b
½ NPK + FM-Fermented (20Mg ha^{-1})	0.06 a	8.21 ab	116 ab	0.66 ab
NPK (175-85-60 kg ha^{-1})	0.07 a	8.75 a	131 a	0.70 a

Means followed by same letter are statistically non significant at $P \leq 0.05$;
Each value is an average of four replications

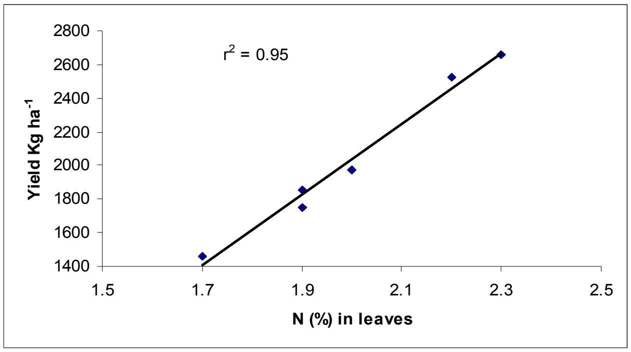

Figure 1. Relationship of N (% in leaves) with the yield of seed cotton

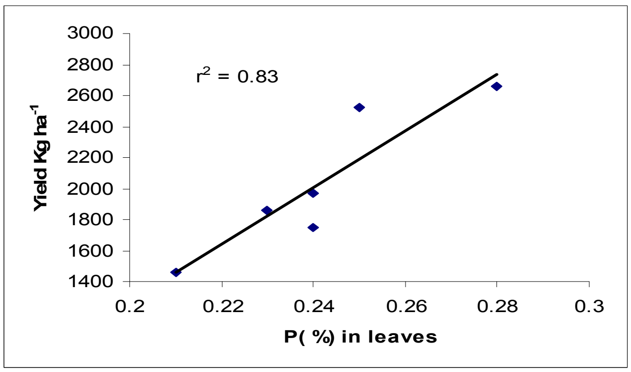

Figure 2. Relationship of P (% in leaves) with the yield of seed cotton

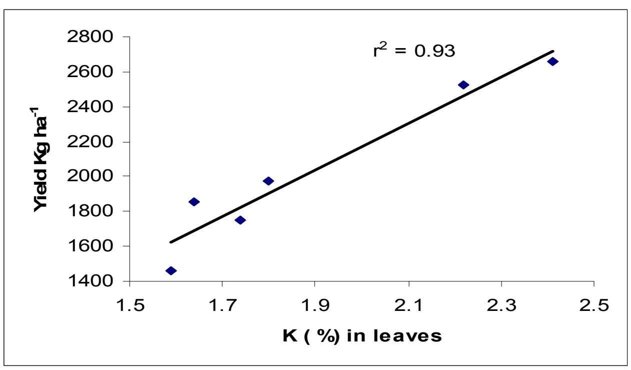

Figure 3. Relationship of K (% in leaves) with the yield of seed cotton

In case of nitrogen concentration in soil, the maximum N was recorded in NPK followed non significantly by ½ NPK +FM –Fermented and other treatments. The trend was as NPK≥ ½ NPK+FM-Fermented ≥ ½ NPK+FM ≥ FM-Fermented ≥ FM ≥ Control. The correlation coefficient curve (Fig. 4) showed a +ve trend (r^2= 0.96) towards seed cotton yield available from the organic manure and mineral fertilizers.

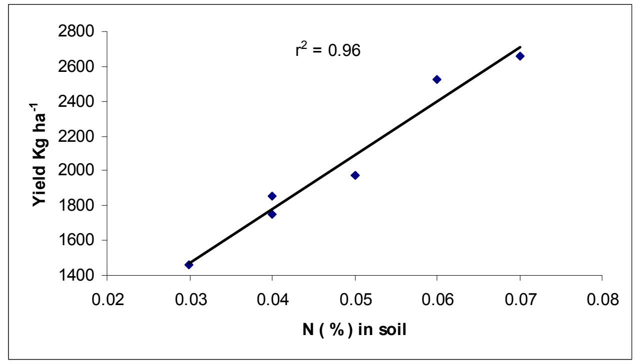

Figure 4. Relationship of soil N (%) with the yield of seed cotton

In case of phosphorus, maximum P conc. was noted in NPK (recommended dose) and followed non significantly by ½ NPK +FM- Fermented and trend was NPK>½ NPK+FM-Fermented ≥ ½ NPK+FM ≥ FM-Fermented ≥FM ≥ Control. The correlation coefficient curve (Fig. 5) showed +ve correlations (r^2=0.94) of seed cotton yield, as the phosphorus concentration increases the yield of the crop also increases and vice versa.

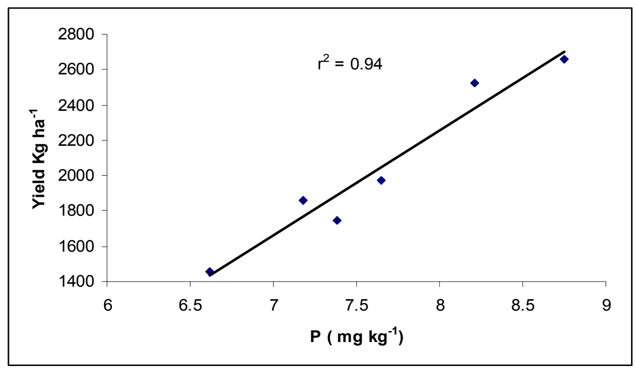

Figure 5. Relationship of soil P (mg kg^{-1}) with the yield of seed cotton

In case of Potassium (K), the statistical interpretation of the data indicated that the maximum K was (131 where recommended dose of NPK were applied and followed by ½ NPK + FM -Fermented (116). Both these treatment differed significantly from each other and control. The coefficient of correlation curve (Fig. 6) showed a +ve (r^2=0.91) yield trend with the increase in the availability of K in soil.

In case of organic matter (OM), almost similar trend was noted as with the availability of NPK, the maximum OM was observed in NPK treatment and followed non significantly by ½ NPK + FM – Fermented. All the treatment differs significantly from control. The trend was NPK ≥ ½ NPK + FM –Fermented ≥ ½ NPK + FM> FM-Fermented) FM and Control. The correlation coefficient curve showed the positive yield trend with the increase in the organic matter in soil (r^2=0.76) (Fig. 7). As the availability of organic matter increases in soil the yield of crop also increases.

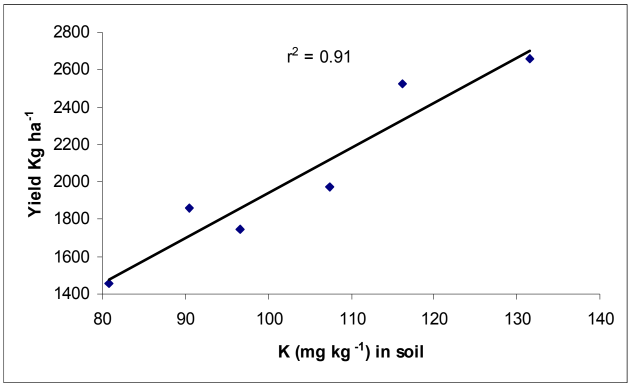

Figure 6. Relationship of soil K (mg Kg^{-1}) with seed cotton yield

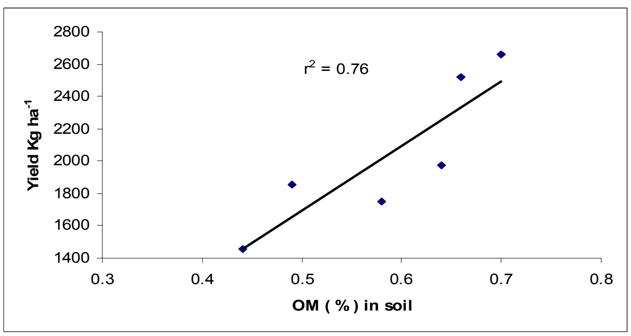

Figure 7. Relationship of soil OM (%)with seed cotton yield

***Economic consideration of seed cotton yield*:** The data in Table 4 indicated the maximum net benefit of cotton crop and marginal rate of net return with VCR. Addition of full dose of NPK increased the net return of Rs. 133920 where as ½ NPK + FYM-Fermented generated Rs. 125220 which is very close to the mineral fertilizer dose. These results were supported by Yaduvanshi (2003), Yinbo *et al.* (1997) and Khaliq *et al.* (2006) who concluded that the integration of organic and inorgnic fertilizers resources are economically viable to sustain crop yield. The law of dominance and marginal analysis indicated that the application of ½ NPK+FM-Fermented is economically more viable (3380.9 % MRR) than the recommended dose of NPK and other treatments.

DISCUSSION

The cotton crop was cultivated in Kharif seasons to evaluate the effect of farm manure and mineral fertilizer with and without the inoculation of Effective Microorganisms. FM, which was treated with microorganisms were named as FM –Fermented. The results of the experiments (Tables 1, 2 and 3) indicated that the application of recommended dose of NPK proved to be best in case of growth, yield and the nutrients concentration in leaves and soil. The combined application of ½ NPK+FM-Fermented also performed well as compared to the recommended dose of NPK. Both these treatments were statistically at par to each other's. Regarding the economic consideration (Table 4), the application of ½ NPK +FM-Fermented was more viable rather than the recommended dose of NPK.

The increase in growth parameters of cotton crop with the application of mineral fertilizers was due to a substantial

Table 4. Marginal Rate of Net return (Byerlee, 1988)

Treatments	Variable cost (Rs.)	Net benefit (Rs.)	Change in cost (Rs.)	Change in benefit (Rs)	MRR (%)	VCR
Control	-	73740				
FM@20 Mg ha-^{1}	1998	90960	2028	17220	849.10	45
FM-Fermented@20 Mg ha-^{1}	2880	89760	882	-1200	-1.36	31
½ NPK + FM (20 Mg ha-^{1})	8190	95400	5310	5640	106.80	11
½ NPK+FM-Fermented (20Mg ha-^{1})	9066	125220	882	29820	3380.90	13
NPK (175-85-60 kg ha-^{1})	12378	133920	3306	8700	263.10	11

$$\textbf{Marginal rate of return (MRR)} = \frac{\text{Marginal net benefits}}{\text{Marginal cost}} \times 100 = (\%)$$

Marginal cost = The increase in variable cost which occurs in changing from one production alternative to another

Marginal net benefit = The increase in net benefit which can be obtained by changing one production alternative to another

Dominance = The treatment which has higher cost but lower net benefits

Variable cost = Cost that varies for a particular treatment buildup of the total and readily available levels of soil nutrients due to the application of mineral fertilizers (Alam *et al.,* 1998; Tejada *et al.,* 2003 and Rathke *et al.*, 2005). The use of mineral fertilizer has some importance over farm manure because it supplies readily the nutrients to crop which help to boost up the growth and yield. (Fixon and Weast, 2002; Manna *et al.,* 2005 and Meng *et al.,* 2005). These mineral fertilizers are the rich source of nutrients and (Lamp, 2000) contributing to it various ways (Haq *et al.,* 2002).

The farm manure is also rich source of nutrients which helps to improve the crop yield and the reduction in yield is might be due to slow and sustainable release of the nutrients. The increase in ½ NPK +FM-Fermented might be due to high level of microbial activity which enhanced organic matter decomposition as well as release of plant available nutrient. The combined application of organic and mineral fertilizer has the potential to improve yield and soil quality parameters (Hussain *et al.,* 1999; Lamp, 2000; Kahliq *et al.,* 2006 and Idress, 2003). The inoculation of effective microorganism with the manure helped to build up the nutritional status of the soil and also improve the efficiency of added fertilizers in soil (Haq *et al*., 2002; Javaid and Bajwa, 2011).The combination of manure and NPK increased significantly the dry matter yield and confirm the effectiveness of NPK from organic manures with reference to control. The treatments which are not receiving any application of mineral fertilizer and manure, clearly indicates the deficiency of N. The application of enriched manure such as compost resulted to increase in K and P in plants (Soumare *et al.,* 2003; Soumare *et al.,* 2002).

Higher concentration of nitrogen in recommended dose of NPK was might be due to the maximum release of nutrient in the soil resulted to improve the nitrogen concentration in soil. The integration of farm manure resulted to enhance the efficiency of mineral fertilizer sources, which resulted to build up the nitrogen status in soil (Higa and Wididana, 1991).

The nitrogen rates from the organic and mineral nutrients resulted in the increase in yield and the quality of soil (Patra *et al.,* 2000; Erhart *et al.,* 2005). It is also clear that the mineral sources of the nutrients are readily available to the plants (Alam, 2005) whereas organic resources inoculated with beneficial microorganism produce a slow release of the nutrients (Higa *et al*., 1993; Hussain *et al.,* 2002; Patra *et al.,* 2000). The combined application of fertilizer N and P may be necessary for increased crop production and soil fertility (Meng *et al.*, 2005). They also suggested that manures had greater effect on increasing soil organic C and N and improving the physical properties. The inoculated manure as compost has been found to improve organic matter status and enhance nutrient supply to plants (Giusquiani *et al.*, 1995; Parkinson *et al.,* 1999) this may help to minimize the additional use of mineral fertilizers in conventional agriculture and help to adopt the concept of organic farming (Erhart *et al.*, 2005).

The analysis of the yield components indicates that the organic components acted as a slow and steady release source of nitrogen on a medium level. The component of yield showed that the plants received sufficient nitrogen from compost at early growth stages and after pollination. At booting stage, when N uptake is highest in plants from compost treatments it was comparable to that with the mineral fertilization (Erhart *et al.,* 2005). The organic fertilizers and biological N2 fixation might be a substantial source of N depending on the farming system (Rathke, 1999; Diepenbrock, 2000; Rathke *et al.,* 2005). The increase in the availability of P and K indicated that fermented manures with the beneficial microorganisms supplied these nutrients into the soil (Ouedraogo *et al.,* 2001; Soumare *et al.*, 2002). The combined use of organic and mineral fertilization resulted to increase the availability of phosphorus in soil which ultimately resulted to build up of soil quality that resulted in better crop growth (Parharm *et al.,* 2002; Saleque, 2004).

The combined applications of organic and mineral fertilizers maintain soil organic matter in soil, resulted in the increases in crop yield (Manna *et al.,* 2005; Sena *et al.,* 2002). The yield of the crop has significant correlation with availability of K in soil, as the level of potassium increases with the addition of organic and mineral fertilizer treatments with and without FM Fermented resulted to increase in K concentration in soil; ultimately resulted to increase yield. (Hussain *et al.*, 1999; Hussain *et al.,* 2002; Alam *et al*., 2005).

Regarding the economic anlaysis, it was clear that the application of ½ NPK+FM-Fermented had a maximum marginal rate of return (MRR) 3380.9 % as compared with the recommended dose of NPK (263.1%).

***Conclusions*:** The investigation reported in these studies indicates some distinctive benefits of combined application of farm manure and mineral fertilizers together with the addition of FM-Fermented (formulated by the inoculation of beneficial microorganism). The results of the experiments indicated that the integration of ½ NPK + FM-Fermented was similar to the recommended dose of mineral fertilizers in case of growth parameters, nutrient concentration (N, P, and K) in leaves and in soil.

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