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Effect of organic and inorganic sources of nutrients on yield, nutrient uptake and soil fertility of maize (*Zea mays*)—mustard (*Brassica campestris*) cropping system*

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Maize *(Zea mays* L.)–mustard *(Brassica campestris* var. *Black toria*) cropping sequence is the most predominant one in sub-tropical hill ecosystems of north-eastern region (NER) of India. Mustard has been a potential crop in winter *(rabi*) season due to its wider adaptability and suitability to exploit residual moisture. The productivity of this system in NER is lower than the national average due to improper and imbalance nutrient use. Both the crops are nutrient-exhaustive and deplete soil fertility extensively. Poor recycling of organic sources also leads to emergence of multiple nutrient deficiencies (Kumar 2008). Hence, judicious nutrient management planning in a system perspective is the need of the hour. Keeping this in mind, present study was conducted to find out the effect of integrated application of inorganic fertilizer, *Azolla* compost and farmyard manure on the productivity of maize – mustard cropping system, soil fertility and economics in the mid-altitude sub-tropical Meghalaya.

Field experiment was conducted at upland farm, ICAR Research Complex for NEH Region, Umiam, Meghalaya under rainfed condition during 2004–06**.** The institute farm is located at 25°30'N latitude, 91°51'E longitude and 950 m altitude. The soil was sandy loam in texture having 1.19 g/cm^3 bulk density, 2.67 g/cm^3 particle density, 51% total porosity, 49.7% maximum water-holding capacity, low in available N (184.6 kg/ha), P (9.38 kg/ha) and medium in available K (241.5 kg/ha) with acidic reaction (*p*H 5.1) and high organic carbon content (1.24%). The annual average rainfall received were 1 508 mm and 614 mm during the maize- and mustard-growing season, respectively.

Experiment in maize was conducted in randomized block design with 7 treatment combinations, viz T_1 (Control), T_2 (100% NPK 60: 60: 20 kg/ha), T_3 (100% NPK + *Azolla* compost 2.5 tonnes/ha), T_4 (100% NPK + farmyard manure 2.5 tonnes/ha), T_5 (50% NPK 30: 30: 20 kg/ha + *Azolla* compost 5 tonnes/ha), T_6 (50% NPK + farmyard manure 5 tonnes/ha), T_7 (*Azolla* compost 5 tonnes/ha + farmyard manure 5 tonnes/ha) and replicated thrice. For succeeding mustard crop a uniform dose of 50% NPK (25: 30: 15 kg/ha) was applied and performance of mustard was studied along with residual effect of treatments from preceding crop. Well-decomposed FYM and *Azolla* compost as per treatment were applied in furrow 15 days before sowing. The average NPK content in FYM and *Azolla* compost on dry weight basis were 0.81, 0.22, 0.85% and 2.57, 0.59, 1.97% respectively. Urea, single superphosphate and muriate of potash were used as inorganic fertilizer sources of N, P and K, respectively. Nitrogen was applied in 3 splits (50% at sowing, 25% at knee-high stage and 25% at silking stage) in maize and in 2 splits (50% at sowing and 50% at 30 days after sowing) in mustard. 'RCM 1-1' maize was sown in the first fortnight of May while 'M 27' (*toria*) mustard in the first week of October. All other recommended practices for both the crops were followed.

Production efficiency (kg/ha/day) was calculated by dividing system maize equivalent yield with total duration of the crop sequence. Maize equivalent yield was obtained by dividing the economic value of the produce (yield of produce (tonnes/ha)×price of produce (Rs/tonne)) with the price of the maize (Rs/tonne). Plant samples were analyzed for total N using a micro-kjeldahl method, while total P and K were determined as per procedure described by Prasad *et al*. (2006). The post-harvest soil samples were collected from 0–20 cm depth for analyzing available nutrient status. Soil samples were analyzed for alkaline permanganate oxidizable N, O.5 M $NaHCO_3$-extractable P and I N NH_4OAC-exchangable K. Net returns in terms of Rs/ha/day was obtained by net monetary returns of the sequence divided by total duration of the crop sequence. Benefit : cost ratio (B : C ratio) was obtained by dividing the gross income with cost of cultivation.

*Short note

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Table 1 Effect of organic and inorganic sources of nutrients on yield attributes of maize and mustard (2 years pooled data)

Treatment	Maize					Mustard				Maize
	Cobs/ m^2	Cob length (cm)	Grains/ Cob	1 000-grain weight (g)	Grain yield (tonnes/ha)	Silliqua/ plant	Seeds/ silliqua	1 000-seed weight (g)	Seed yield (tonnes/ha)	equivalent yield (tonnes/ ha)
Control	5.10	8.20	140.3	185.1	1.58[a]	138	8.85	3.76	0.62[a]	3.43[a]
100% NPK (50: 60: 30 kg/ha)	6.85	13.88	325.4	228.4	2.93[bc]	186	10.05	4.13	1.00[bc]	5.61[b]
100% NPK + *Azolla* compost 2.5 tonnes/ha	7.45	16.87	385.3	261.6	3.21[c]	192	10.52	4.24	1.11[bc]	6.51[c]
100% NPK + FYM 2.5 tonnes/ha	7.28	16.64	366.8	259.4	3.16[c]	190	10.26	4.32	1.07[bc]	6.36[c]
50% NPK + *Azolla* compost 5 tonnes/ha	7.40	15.95	360.2	259.0	3.10[c]	215	10.73	4.70	1.08[bc]	6.34[c]
50% NPK + FYM 5 tonnes/ha	6.95	15.88	354.5	253.7	3.06[bc]	209	10.75	4.73	1.10[bc]	6.37[c]
Azolla compost 5 tonnes/ha + FYM 5 tonnes/ha	7.10	14.50	333.0	250.5	2.84[b]	221	11.42	4.71	1.23[c]	6.52[c]
CD ($P = 0.05$)	0.33	2.4	29.5	7.3	0.26	27.6	1.5	0.16	0.21	0.65

Values in each column sharing same letter are not significantly different ($P< 0.05$); FYM, farmyard manure

Application of 100% NPK + *Azolla* compost 2.5 tonnes/ha recorded maximum kernels/cob, number of cobs/m^2, 1000 grain weight and cob length, followed by 100% NPK + farmyard manure 2.5 tonnes/ha. The response of combined application of *Azolla* compost 5 tonnes/ha + farmyard manure 5 tonnes/ha on yield attributes was statistically similar to 100% NPK alone (Table 1).

Maximum maize grain yield (3.21 tonnes/ha) was recorded with conjunctive application of 100% NPK + *Azolla* compost 2.5 tonnes/ha, followed by of 100% NPK + farmyard manure 2.5 tonnes/ha. These 2 treatments were at par with application of 50% NPK + *Azolla* compost or farmyard manure 5 tonnes/ha, 100% NPK alone and *Azolla* compost 5 tonnes/ha + farmyard manure 5 tonnes/ha (Table 1). Pooled grain yield obtained with application of 100% NPK + *Azolla* compost 2.5 tonnes/ha was 103.2% and 9.6% higher than the control and recommended NPK, respectively. Higher grain yield with combined application of inorganic and organic sources of nutrients could be ascribed to efficient utilization of nutrients from combined sources compared to the single source. These findings were in agreement with the observation of several other researchers (Nanjappa *et al.* 2001, Mahala *et al*. 2006). Organic manures, like farmyard manure also supply micronutrients beneficial to the crop growth and productivity (Das *et al*. 2006). Substitution of 100% inorganic fertilizers with *Azolla* compost 5 tonnes/ha + farmyard manure 5 tonnes/ha gave grain yield similarto 100% NPK. *Azolla* contained a good amount of Ca (0.05%), Mg (0.05%) and Fe (0.21%), besides some essential amino acids and vitamins. Organic manure acts as nutrient reservoir and upon decomposition produces organic acids, thereby adsorbed ions are released slowly for the entire growth period leading to higher yields (Kumar *et al.* 2005).

In mustard, the highest number of siliqua/plant, 1000 seed weight and seed yield were recorded with residual effect of *Azolla* compost 5 tonnes/ha + farmyard manure 5 tonnes/ha applied to preceding maize crop. This effect was at par with residual effect of 100% NPK + *Azolla* compost or farmyard manure 2.5 tonnes/ha as well as 50% NPK + *Azolla* compost or farmyard manure 5 tonnes/ha (Table 1). The seed yield obtained with residual effect of *Azolla* compost 5 tonnes/ha + farmyard manure 5 tonnes/ha was 99% and 37% higher than yield obtained with residual control and recommended NPK, respectively. Beneficial effect of organic manure alone or in combination with inorganic fertilizer applied to preceding crop on the productivity of succeeding crop was also observed by Das *et al*. (2004).

Highest system productivity in terms of maize equivalent yield was obtained from *Azolla* compost 5 tonnes/ha + farmyard manure 5 tonnes/ha in maize and its residual effect on mustard (Table 1). This was at par with 100% NPK + farmyard manure 2.5 tonnes/ha, 50% NPK + *Azolla* compost 5 tonnes/ha or farmyard manure 5 tonnes/ha. Conjunctive application of inorganic and organic sources at either of the level (100% NPK + *Azolla* compost or farmyard manure 2.5 tonnes/ha or 50% NPK + *Azolla* compost or farmyard manure 5 tonnes/ha) in maize enhanced the productivity of succeeding mustard and thereby improved system productivity. These findings were in close agreement with the results of Kumpawat (2004) and Kumar *et al*. (2005a).

The N, P and K uptake by maize and mustard followed the trend similar to their respective seed yield (Table 2). Additional amount of nutrient supplied by *Azolla* compost or farmyard manure as well as the beneficial effects of organic

Table 2 Nutrient uptake and soil fertility at final harvest (kg/ha) as influenced by organic and inorganic sources of nutrients (2 years pooled data)

Treatment	Nutrient uptake (kg/ha)						Soil fertility at final harvest (kg/ha)			Organic carbon (%)
	Maize			Mustard						
	N	P	K	N	P	K	N	P	K	
Control	32.5	9.8	27.3	22.1	5.39	13.9	173.4	7.35	228.4	1.22
100% NPK (50: 60: 30 kg/ha)	82.2	17.5	75.4	30.3	7.56	23.7	187.4	9.44	245.6	1.30
100% NPK + *Azolla* compost 2.5 tonnes/ha	94.6	20.3	83.6	40.2	9.93	27.8	191.3	10.10	244.3	1.41
100% NPK + FYM 2.5 tonnes/ha	92.8	19.6	81.8	39.8	9.56	28.2	189.2	9.83	247.3	1.45
50% NPK + *Azolla* compost 5 tonnes/ha	91.7	19.4	82.3	41.8	10.8	30.2	193.7	10.63	247.8	1.52
50% NPK + FYM 5 tonnes/ha	89.4	18.7	80.4	41.6	11.2	28.8	192.3	10.41	246.6	1.50
Azolla compost 5 tonnes/ha + FYM 5 tonnes/ha	84.6	18.4	78.8	45.7	12.8	33.3	194.8	11.63	249.7	1.49
CD ($P = 0.05$)	11.23	2.42	6.06	5.64	0.57	3.13	17.08	1.57	NS	0.10

FYM, Farmyard manure

matter addition derived in connection with the improvement in physico-chemical properties of the soil was the reason of higher nutrient uptake.

At final harvest, highest soil fertility in terms of available N, P and K was observed when *Azolla* compost 5 tonnes/ha + farmyard manure 5 tonnes/ha was applied in maize (Table 2). This was at par with available NPK status of all other treatments except control, which recorded significantly lower available NPK status. Application of *Azolla* compost 5 tonnes/ha + farmyard manure 5 tonnes/ha to maize recorded available N, P and K status of 194.8, 11.63 and 249.7 kg/ha, respectively, which was 12.3, 36.8 and 9.3% higher than the control. The extent of increase in N, P and K status with 100% inorganic treatment was 8, 28.4 and 7.53% over control respectively. Increase in available N and P might be due to the direct addition of N through *Azolla* compost/farmyard manure and increased multiplication of soil microbes, which might have converted organically bound N to inorganic form. Increase in phosphorus availability was also due to the fact that organic materials form a cover on seasquioxides and thus reduce the phosphate, fixing capacity of the soil and increased phosphorus solublization for the native soil pool (Kumar *et al.* 2005).

Highest soil organic carbon content at final harvest was recorded with 50% NPK + *Azolla* compost 5 tonnes/ha (1.52%) which was 24.6 and 17% higher than control and recommended NPK, respectively. Table 2 revealed that those treatments received organic manures with or without fertilizer recorded the similar soil organic carbon values. Improvement in soil organic carbon due to addition of organic manures compared to the recommended N, P and K alone was also reported by Ramesh *et al.* (2009).

Production efficiency was maximum with combined application of *Azolla* compost 5 tonnes/ha + farmyard manure 5 tonnes/ha (23.6 kg/ha/day) to maize along with its residual effect on mustard. This was followed by integrated application of 100% NPK+ *Azolla* compost or farmyard manure 2.5 tonnes/ha (23. 5 kg/ha/day) or 50% NPK + *Azolla* compost or farmyard manure 5 tonnes/ha (23 kg/ha/day).

Considering the whole cropping system, the gross returns were maximum (Rs 40 755/ha) with *Azolla* compost 5 tonnes/ha + farmyard manure 5 tonnes/ha, followed by 100% NPK + *Azolla* compost 2.5 tonnes/ha. On contrary net returns/ha/day were highest with 100% NPK + *Azolla* compost 2.5 tonnes/ha, followed by 100% NPK + farmyard manure 2.5 tonnes/ha. Application of 50% NPK + *Azolla* compost or farmyard manure 5 tonnes/ha and *Azolla* compost 5 tonnes/ha + farmyard manure 5 tonnes/ha recorded comparatively lower net returns mainly because of higher expenses incurred with organic manure. Maximum B: C ratio was obtained with conjunctive application of 100% NPK + *Azolla* compost 2.5 tonnes/ha (2.20), followed by 100% NPK + farmyard manure 2.5 tonnes/ha (2.15) and 100% NPK (2.04). Unlike gross returns, the B: C ratio obtained with combined application of *Azolla* compost 5 tonnes/ha + farmyard manure 5 tonnes/ha to maize was much lower than all other treatments but higher than control (1.39). It could be ascribed to higher expenses incurred to organic manure and lower marginal returns with these sources. Improvement in soil health due to continuous application of organic manure, if converted in to monetary term, application of organic manures would definitely provide higher returns.

SUMMARY

In north-eastern region of India, improper and imbalance nutrient use in maize–mustard cropping system leads to poor system productivity. Maize being an exhaustive crop also depletes soil fertility. The study on judicious integrated nutrient management strategy revealed that application of full dose of inorganic fertilizer along with *Azolla* compost 2.5 tonnes/ha application to maize not only enhanced productivity of maize-mustard cropping system by 90% and 13.4% over the control and recommended N, P and K respectively, but also improved soil fertility in terms of higher

available N, P, K and organic carbon. This nutrient management option had considerable residual effect on succeeding mustard in terms of yield and income. However, maximum residual effect on mustard in terms of yield attribute and yield was recorded when whole nutrient was applied using organic manure *(Azolla* compost + farmyard manure).

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