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Integrated Nutrient Management Package for Field Cultivation of Makhana in North Bihar

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ABSTRACT

Makhana (*Euryale ferox* Salisb.) cultivation in field conditions has just begun, making it imperative to develop an integrated nutrient management (INM) package for realizing the yield potential of makhana in north Bihar. A three year experiment was carried out. Application of NPK @75:45:30 kg ha^{-1} led to a yield improvement of 10% over control, with an additional improvement of 8.2% by NPK @100:60:40 kg ha^{-1}, which was 19% higher than the yield under control. No yield increment was recorded with further increase in NPK *i.e.* @125:75:50 kg ha^{-1}. However, NPK@100:60:40 kgha^{-1} in combination with FYM @20 t ha^{-1} caused 22% yield enhancement over NPK @100:60:40 kg ha^{-1} and 45.2% over control. Even the sole application of FYM @20 t ha^{-1} resulted in 28% higher yield compared to control and 7.6% yield advantage over NPK @100:60:40 kg ha^{-1}. Clearly, makhana yield was boosted by both NPK and FYM, applied alone or in combination. However, the effect of FYM was more pronounced than that of NPK, implying that the yield of makhana was not limited as much by NPK availability as by the factors contributed by FYM application. FYM-induced increases in organic C and micronutrients could be credited for better yield boosting effect of FYM. To conclude, an INM package consisting of NPK @100:60:40 kg ha^{-1} with FYM @20 t ha^{-1} is recommended for materializing the yield potential of makhana in field conditions of north Bihar.

KEYWORDS
Black diamond, Fox nut, Gorgon nut, Micronutrients, NPK fertilization, Soil fertility

INTRODUCTION

Makhana (*Euryale ferox* Salisb.) is an important aquatic cash crop grown primarily in north Bihar, which contributes nearly 80% to the total makhana production in India. In view of the growing awareness about nutritional and medicinal values of makhana, its demand has been on rise globally (Das *et al*., 2006, Kumar *et al*., 2016a, Jha *et al*., 2018, Kumar *et al*., 2020). Conventionally, makhana is being grown in the ponds and perennial water bodies particularly by the fishermen communities of north Bihar (Kumari *et al*., 2014). However, to meet its rapidly growing demand, both the productivity and the area under makhana cultivation need to be increased. As the number of ponds and natural water bodies are believed to decline gradually, introduction of makhana cultivation in field condition, like rice, may be required for further expansion of the area under makhana (Kumar *et al*., 2011). The perceived benefits include better harvesting efficiency of makhana seeds leading to higher productivity in field, and possible inclusion of makhana as a component crop in cropping sequences common to north Bihar (Kumar *et al*., 2020). Conventionally, no external fertilization is given to makhana growing in ponds as the pond systems are self-sustaining in nutrient supply due to decomposition of the leftover plant biomass post makhana harvesting. However, under intensive cultivation in field conditions, where more than a single crop (makhana) is to be taken, external application of nutrients would be required to sustain nutrient supply to the growing plants and the crop/s that follow. However, the appropriate doses of nutrients are yet to be determined for optimum productivity of makhana under field cultivation. Soil organic carbon has particularly been reported to be a major determinant of makhana productivity in ponds (Dutta *et al*., 1986). It's therefore pertinent to examine the effects of external addition of organic manures on makhana productivity in field condition. Integrated nutrient management (INM) aims to optimize nutrient supply to crop with the objectives of adequate plant nutrition, increase crop productivity and improvement in soil health. The basic concept of INM approach is the maintenance and possible improvement of soil for long-term sustained productivity and using different sources of nutrients in conjunction. Since field cultivation of makhana is a concept of recent origin, INM package for the same is yet to be standardized based on elaborate field experimentations. Thus, in order to develop an INM package and to assess the effect of INM practices on makhana productivity and soil properties, a three-year field experiment was conducted at the research farm of ICAR Research Complex for Eastern Region, Research Centre for Makhana, Darbhanga, Bihar.

MATERIALS AND METHODS

Field experiment was conducted for consecutive three years on the research farm of ICAR RCER RCM, Darbhanga. Before initiation of the experiment, a composite soil sample was drawn from the experimental farm and analyzed for its physico-chemical properties as per the standard procedures prescribed by Page *et al*. (1982). The soil was silty clay loam in texture with bulk density 1.52 Mg m^{-3}. Soil pH was 7.6 with the organic carbon 0.35%, available nitrogen 210 kg ha^{-1}, available phosphorus 17 kg ha^{-1} and available potassium 220 kg ha^{-1}. Available Fe, Mn, Cu and Zn were

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found to be 30.0, 18.0, 1.06 and 0.40 mg kg^{-1}, respectively. Nursery was raised during January to March, and transplantation of makhana in experimental plots ($30m^2$ in size) was done in the last week of March. The crop was grown with 06 treatments (Table 1), each with four replications, laid out in Randomized Complete Block Design (RCBD).

Table 1: Description of treatments used in the study

Treatments	Treatments' description
T_1	Control (no fertilizer or manure applied)
T_2	N:P:K @75:45:30 kg ha^{-1}
T_3	N:P:K @100:60:40 kg ha^{-1}
T_4	N:P:K @125:75:50 kg ha^{-1}
T_5	N:P:K @100:60:40 kg ha^{-1}+FYM @20 t ha^{-1}
T_6	FYM @20 t ha^{-1}

Makhana seedlings were transplanted with a line to line and plant to plant distance of 1.0 m each. A water level of at least 1.0 fit was maintained uniformly throughout the growing season as suggested by Kumar *et al*. (2011). Weeding was done twice within 45 days of transplanting. After maturity, seed yield was recorded once the seeds were harvested in the month of August using the local bamboo-made device called *Gaanja.* Composite soil samples were drawn from each plot for analysis of the physico-chemical properties and nutrients' availability as influenced by the treatments used in the experiment. The pooled data obtained from three years of experimentation were analyzed using the SPSS 16.0 statistical software. Significance of difference in the mean values of the yield and soil parameters was judged at $P \leq 0.05$.

RESULTS AND DISCUSSION

We made some very interesting and decisive observations regarding effects of various doses and combinations of NPK and FYM on seed yield of makhana (Fig.1). Application of NPK @ 75:45:30 kg ha^{-1} (T_2) led to a yield improvement of 10% over control (T_1), with an additional improvement of 8.2% by NPK application @100:60:40 kg ha^{-1} (T_3), which was nearly 19% higher than the yield under absolute control. Interestingly, no significant yield increment was recorded with further increase in NPK application *i.e.* @125:75:50 kg ha^{-1} (T_4). However, when T_3 was combined with FYM @ 20 t ha^{-1} (*i.e.* T_5),

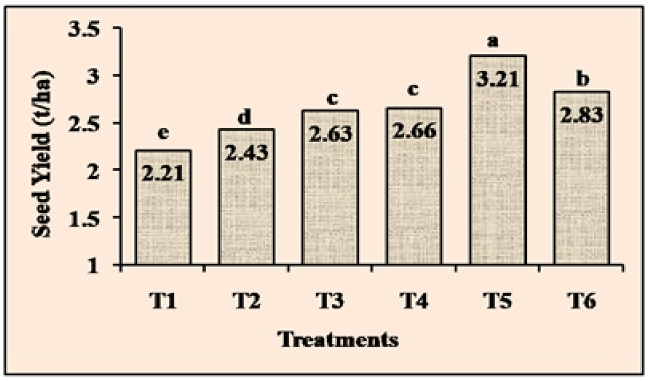

Fig. 1: Effect of various doses and combinations of fertilizers and manures on seed yield of makhana. Different letter/s at the top of bars shows significant difference in the yield at $P \leq 0.05$ (*Treatment descriptions are given in* table 1)

it led to a yield improvement of 22% over T_3 and 45.2% over control. Even the sole application of FYM @ 20 t ha^{-1} (*i.e.* T_6) resulted in 28% higher yield compared to control and 7.6% yield advantage over NPK @100:60:40 kg ha^{-1} (T_3).

Clearly, yield of makhana seed was boosted by both NPK as well as FYM application, applied either alone or in combination. However, the effect of FYM was more pronounced than that of NPK application.

From the observations related to yield, physico-chemical properties and nutrients' availability in soil (Table 2 to 4). It becomes amply evident that the yield of makhana on the experimental soil was not limited as much by NPK availability as by the factors contributed by FYM application.

Apparently, available Cu and Zn along with organic carbon showed the most striking improvement in soil consequent to FYM application (*i.e.* in T_5 and T_6), which could be credited for better yield boosting effect of FYM than the NPK fertilization. Initial soil properties also confirm that available NPK was not as much deficient as the available Zn and organic C. However, the concurrent increase in yield with increasing availability of Cu, which was not at all deficient in the experimental soil, makes and interesting observation, based on which a relatively higher nutritional requirement of Cu for makhana growth and yield can also not be denied. And this may be attributed to the beneficial role of Cu in the reproductive

Table 2: Basic soil properties and primary nutrients' availability as influenced by doses and combinations of NPK and FYM application

Treatments	pH	EC (dS m^{-1})	Org. C (%)	Av. N (kg ha^{-1})	Av. P (kg ha^{-1})	Av. K (kg ha^{-1})
T_1: Control	7.6	0.24	0.55	225	27	231
T_2: NPK@75:45:30 kg ha^{-1}	7.4	0.28	0.58	234	31	245
T_3: NPK@100:60:40 kg ha^{-1}	7.3	0.28	0.66	245	33	250
T_4: NPK@125:75:50 kg ha^{-1}	7.0	0.30	0.68	253	40	255
T_5: T_3+FYM @20 t ha^{-1}	6.6	0.36	0.83	285	48	261
T_6: FYM @20 t ha^{-1}	6.9	0.32	0.80	240	30	240
C.D. (*P*=0.05)	0.4	0.05	0.03	6.0	4.0	5.6

phase of the plant growth, particularly during flowering and seed formation. Increasing seed yield with increased Zn availability, caused by FYM addition, can be understood given the fact that Zn availability in the experimental soil (0.4 mg kg^{-1}) was much below the critical limit for DTPA Zn (0.8 mg kg^{-1}) proposed by Lindsay and Norvell. (1978). A strongly positive association of organic carbon with biomass yield of makhana in pond system is a well-established fact (Dutta *et al*., 1984).

Soil pH was reduced due to application of both NPK fertilizers as well as FYM (Table 2), which can be attributed to the acid producing behavior of the fertilizers applied and possible increase in organic acids subsequent to decomposition of applied manure. On the other hand, EC of the soils increased particularly at higher dose of NPK (T_4) and FYM application (T_5-T_6). Particularly noticeable was the reduction in bulk density of the soils due to FYM applications (T_5-T_6) for consecutive 3 years, with an associated rise in porosity as well as water holding capacity of the soils (Table 3). This might have allowed better root growth, root penetration and proliferation in soil which could have led to better nutrient uptake by the plants, resulting in more pronounced yield improvement in the treatments involving FYM application. Improved buffering capacity of the soils with higher organic matter content might also have led to a better nutrition of the plants, resulting in higher yield under FYM treatments.

Table 3: Physical properties of the soils as influenced by doses and combinations of NPK and FYM application

Treatments	BD (Mg m^{-3})	PD (Mg m^{-3})	Porosity (%)	WHC at FC (%)	WHC at WP (%)
T_1: Control	1.41	2.48	43.1	40	21
T_2: NPK@75:45:30 kg ha^{-1}	1.36	2.46	44.7	42	23
T_3: NPK@100:60:40 kg ha^{-1}	1.33	2.50	46.8	42	22
T_4: NPK@125:75:50 kg ha^{-1}	1.24	2.45	49.4	43	23
T_5: T_3+FYM @20 t ha^{-1}	1.18	2.41	51.0	48	28
T_6: FYM @20 t ha^{-1}	1.20	2.43	50.6	45	25
C.D. (*P*=0.05)	0.05	0.05	2.84	4.56	NS

As regards the non-responsiveness of makhana yield at higher NPK application (*i.e.* T_4), Liebig's Law of Minimum can be recalled. In the present study, micronutrients availability in the experimental soil might have been the most yield limiting factors which could possibly have denied the probable yield improvement at higher doses of NPK application (Table 4). If so, the possible benefits of higher doses of NPK fertilization can be realized only when sufficient availability of micronutrients is ensured in the soil. Such a criticality of micronutrients for improving crop production has been recently reported by Kumar *et al*. (2016b). The observations call for elaborate experimentations to examine the effects of micronutrients on growth and yield of makhana.

Table 4: Micronutrients' availability (mg kg^{-1}) in the soils as influenced by doses and combinations of NPK and FYM application

Treatments	Fe	Mn	Cu	Zn
T_1: Control	28	20	1.03	0.35
T_2: NPK@75:45:30 kg ha^{-1}	30	20	1.24	0.37
T_3: NPK@100:60:40 kg ha^{-1}	32	23	1.35	0.42
T_4: NPK@125:75:50 kg ha^{-1}	33	23	1.38	0.48
T_5: T_3+FYM @20 t ha^{-1}	42	30	2.12	0.62
T_6: FYM @20 t ha^{-1}	36	25	1.75	0.53
C.D. (*P*=0.05)	4.3	3.4	0.09	0.04

When economics of makhana cultivation was worked out (Table 5), the best B: C ratio was recorded with the combined application of NPK@100:60:40 kg ha^{-1} and FYM @20t ha^{-1} (*i.e.* in INM Treatment, T_5). Remaining treatments, except T_1, were on par with regard to B: C ratios, which were superior to the control. This implies that external fertilization either through chemical fertilizers or organic manure can improve farm income, with the best return being envisaged if INM approach, as recommended, is adopted in makhana cultivation.

Table 5: Effect of doses and combinations of NPK and FYM application on economics of makhana cultivation

Treatments	Gross Return (x $Rs.10^3$)	Net Return (x $Rs.10^3$)	B:C ratio
T_1: Control	199	60	1.43
T_2: NPK@75:45:30 kg ha^{-1}	219	73	1.50
T_3: NPK@100:60:40 kg ha^{-1}	237	84	1.55
T_4: NPK@125:75:50 kg ha^{-1}	239	84	1.53
T_5: T_3+FYM @20 t ha^{-1}	289	118	1.68
T_6: FYM @20 t ha^{-1}	255	94	1.58
C.D. (*P*=0.05)	06	06	0.07

CONCLUSION

An INM package was developed based on the observations from a three-year field experiment with makhana. The package includes NPK application @100:60:40 kg ha^{-1} in conjunction with FYM @20 t ha^{-1}. This INM recommendation will help in materializing to a great extent the yield potential of makhana grown in field conditions in north Bihar. Using this INM package, a yield of as much as 3.2 t ha^{-1} was obtained in present study, which is roughly twice the yield of makhana obtained in pond systems. Further experimentations are required to examine the effects of secondary and micronutrients on growth, yield and quality of makhana in field conditions.

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