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EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON YIELD OF MAKHANA (*Euryale ferox* SALISB.)

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ABSTRACT

Makhana (*Euryale ferox* Salisb.) is an important aquatic cash crop of eastern India, particularly North Bihar, where field cultivation is expanding due to shrinking pond resources. However, standardized nutrient management practices for field-grown makhana are lacking. A three-year field experiment was conducted at the Regional Research Station, Jhanjharpur, Bihar, to assess the effect of integrated nutrient management (INM) on seed yield, soil properties, and economics of makhana. Six treatments comprising graded doses of NPK fertilizers, farmyard manure (FYM @ 20 t ha⁻¹), their combinations, and an unfertilized control were evaluated in a randomized complete block design. Application of NPK @ 100:60:40 kg ha⁻¹ increased seed yield by 19% over control, while higher NPK doses did not result in significant yield improvement. Integration of FYM with NPK (100:60:40 kg ha⁻¹ + FYM 20 t ha⁻¹) produced the highest seed yield, registering a 45.2% increase over control and 22% over sole NPK application. Sole FYM application also enhanced yield by 28% compared to control. INM significantly improved soil organic carbon (0.88%), available nitrogen (298 kg ha⁻¹), phosphorus (53 kg ha⁻¹), potassium (272 kg ha⁻¹), and micronutrient availability, particularly zinc (0.60 mg kg⁻¹) and copper (2.10 mg kg⁻¹). Bulk density declined from 1.42 to 1.20 Mg m⁻³, accompanied by increased porosity and water-holding capacity. The highest benefit–cost ratio (1.67) was obtained under integrated application of NPK and FYM. The study concludes that INM using NPK @ 100:60:40 kg ha⁻¹ with FYM @ 20 t ha⁻¹ is the most effective strategy for improving productivity, soil health, and profitability of field-grown makhana in North Bihar.

Key words: B:C ratio, Farmyard manure, Makhana, Nutrient management, Soil health, Yield

Introduction

Makhana (*Euryale ferox* Salisb. of family Nymphaeaceae) is an important and potential macrophyte aquatic cash crop grown primarily in north Bihar, which contributes nearly 80% to the total makhana production in India. It is also known as fox nut, Gorgan nut, prickly water lily (Shanker *et al.*, 2010). In view of the growing awareness about nutritional and medicinal values of makhana, its demand has been on rise globally (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. 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 fallow. 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 pond (Dutta *et al.*, 1986). 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 conjunction. It's therefore pertinent to examine the effects of external addition of organic manures on makhana productivity in field condition. 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 Regional Research Station, Jhanjharpur, Madhubani.

Materials and Methods

The field experiment was conducted for consecutive three years on the campus farm area of Regional Research Station, Jhanjharpur, Madhubani, Bihar. Before starting the experiment, a composite soil sample was drawn from the experimental farm and analyzed for its

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@80:40:30 kg ha ⁻¹
T ₃	N:P:K@100:60:40 kg ha ⁻¹
T ₄	N:P:K@120:80:50 kg ha ⁻¹
T ₅	N:P:K@100:60:40 kg ha ⁻¹ + FYM@20t ha ⁻¹
T ₆	FYM@20t ha ⁻¹

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⁻¹. 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 found to be 30.0, 18.0, 1.06 and 0.40 mg/kg, respectively. Nursery was raised during January to March, and transplantation of makhana in experimental plots (30m² 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). 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.*, (1911). 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 of difference in the three years of experimentation were analyzed using the SPSS 16.0 statistical software. Significance mean value of the yield and soil parameters was judged at $p < 0.05$.

Results and Discussion

The observations regarding effects of various doses and combinations of NPK and FYM on seed yield of makhana (Fig. 1). Application of NPK @ 80:40:30 kg per ha (T₂) led to a yield improvement of 10% over control (T₁), with an additional improvement of 8.2% by NPK application @100:60:40 kg per ha (T₃), 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. @120:80:50 kg per ha (T₄). However, when T₅ was combined with FYM@20t per ha (i.e.T₅), it led to a yield improvement of 22 percent over T₃ and 45.2 percent over control. Even the sole application of FYM @20t per ha (i.e.T₆) resulted in 28 percent higher yield compared to control and 7.6 percent yield advantage over NPK @100:60:40kg per ha (T₃).

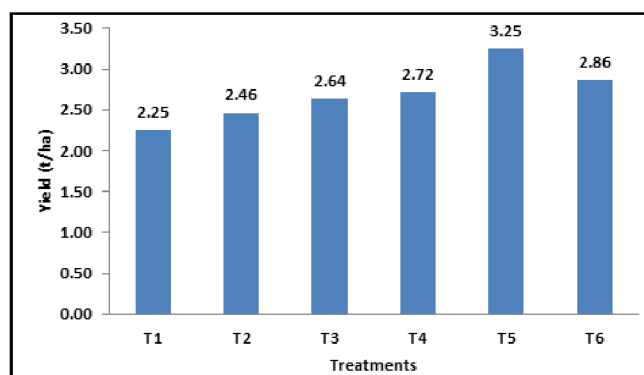


Fig.1: Effect of various doses and combination of fertilizers and manures on seed yield of Makhana. The top of bars shows significant difference in the yield at $p < 0.05$ (Treatment descriptions are given in Table 1).

Table 2: Basic soil properties and primary nutrients availability as influenced by doses and combination of NPK and FYM Application.

Treatments	pH	EC	Org.C(%)	A _v N (kg ha ⁻¹)	A _v P (kg ha ⁻¹)	A _v K (kg ha ⁻¹)
T ₁ : Control	6.8	0.32	0.80	240	30	240
T ₂ : N:P:K@80:40:30 kg ha ⁻¹	6.6	0.36	0.83	282	48	261
T ₃ : N:P:K@100:60:40 kg ha ⁻¹	6.5	0.34	0.84	286	46	266
T ₄ : N:P:K@120:80:50 kg ha ⁻¹	6.2	0.36	0.85	288	48	268
T ₅ : T ₃ +@20tha ⁻¹	6.0	0.34	0.88	298	53	272
T ₆ : FYM@20tha ⁻¹	6.4	0.34	0.83	280	44	261
CD. (P=0.05)	0.1	NS	NS	18	7	17

Table 3: Physical properties of the soil as influenced by doses and combination of NPK and FYM application.

Treatments	BD (Mg m ⁻³) PWP	PD (Mg m ⁻³)	Porosity (%)	WHC at FC(%)	WHC at (%)
T ₁ : Control	1.42	2.48	43.0	40	20
T ₂ : N:P:K@80:40:30 kg ha ⁻¹	1.36	2.47	44.6	41	22
T ₃ : N:P:K@100:50:40 kg ha ⁻¹	1.32	2.50	46.8	42	21
T ₄ : N:P:K@120:60:50 kg ha ⁻¹	1.24	2.46	49.2	43	22
T ₅ : T ₃ +@20tha ⁻¹	1.20	2.42	50.8	46	26
T ₆ : FYM@20tha ⁻¹	1.22	2.44	59.6	44	24
CD. (P=0.05)	0.06	NS	9.8	NS	NS

Obviously, 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.

The available Cu and Zn along with organic carbon showed the most striking improvement in soil consequent to FYM application (i.e. in T₅ and T₆), 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

Table 4: Micronutrients' availability (mg kg⁻¹) in the soil as influenced by doses and combinations of NPK and FYM application.

Treatments	Fe	Mn	Cu	Zn
T ₁ : Control	26	20	1.02	0.34
T ₂ : N:P:K@80:40:30 kg ha ⁻¹	28	20	1.22	0.36
T ₃ : N:P:K@100:50:40 kg ha ⁻¹	30	22	1.34	0.40
T ₄ : N:P:K@120:60:50 kg ha ⁻¹	31	22	1.38	0.46
T ₅ : T ₃ +@20tha ⁻¹	40	28	2.10	0.60
T ₆ : FYM@20tha ⁻¹	34	24	1.73	0.51
CD. (P=0.05)	2	2	0.05	0.07

observation, based on which a relatively higher nutritional requirement of Cu for makhana growth and yield can also not be denied. This may be attributed to the beneficial role of Cu in the reproductive 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 per kg) was much below the critical limit for DTPA Zn (0.8 mg per kg) 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 behaviour of the fertilizers applied and possible increase in organic acids subsequent to decomposition of applied manure. On the other hand,

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

Treatments	Gross Return (× Rs.10 ³)	Net Return (× Rs.10 ²)	B:C ratio
T ₁ : Control	198	60	1.43
T ₂ : N:P:K@80:40:30 kg ha ⁻¹	218	72	1.49
T ₃ : N:P:K@100:50:40 kg ha ⁻¹	236	82	1.53
T ₄ : N:P:K@120:60:50 kg ha ⁻¹	238	82	1.53
T ₅ : T ₃ +@20tha ⁻¹	288	116	1.67
T ₆ : FYM@20tha ⁻¹	252	92	1.58
CD. (P=0.05)	12	9	0.07

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.

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. 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 per ha and FYM @20t per ha (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.

Conclusion

The package and practices of INM 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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