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Integrated nutrient management for okra in an *inceptisol* of eastern India and yield modeling through artificial neural network

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ABSTRACT

Present investigation has been conducted to assess the efficiency of few selected and simulated options of integrated nutrient management and plant growth regulator in improving okra growth and increasing okra yield (*Abelmoschus esculentus* L. Moench) in an *inceptisol* at Gayeshpur, West Bengal, India (23° N 89° E at 9.75 m above MSL). The experimental soils were neutral, non-saline, sandy loam, low in organic carbon, available N, DTPA extractable micronutrients, moderate in available P and medium in available K contents. The experiment was laid out in an asymmetric factorial design with seven different treatments of integrated nutrient management (INM) and two levels of gibberellic acid (GA). Okra yield, macro and micronutrients uptake by okra pod, available nutrient status in post-harvest soil were observed to increase significantly when chemical N and P were supplemented by organic manures and/or bacterial fertilizers along with application of GA. Application of 75% of NP + total K through chemical fertilizers along with *Azospirillum*, PSB, VAM and FYM restored highest soil nutrient availability and okra pod nutrient accumulation. Highest okra yield and best economic return could be achieved when PSB and FYM were used to supplement 75% of N, P + total K. Okra yield models, developed through artificial neural network (ANN), clearly indicated the manifest role of soil and okra pod N, P, Zn, Fe and Mn in increasing productivity under interventions of bacterial fertilizers (PSB and VAM).

1. Introduction

India is the largest producer of okra with 5.78 metric tons annual production from 0.50 million hectare cultivation (average productivity 11.61 t/ha) (National Horticulture Board, 2011). The State of West Bengal is the leading producer of okra in India, with 11.65 t/ha productivity, both of which are miserably below the potential productivity (15–20 t/ha) (Nagel, 2010). Indiscriminate use of inorganic fertilizers with poor balance in N–P–K and virtual absence of micronutrients may deter exploitation of full yield potential of the crop.

Integrated management of nutrients (INM) may harness such discrepancies through maintenance or adjustment of soil fertility/productivity and of optimal plant nutrient supply for sustaining the desired level of crop productivity (FAO, 1995). Supplementation of inorganic fertilizers through manures and bacterial fertilizers were observed to augment yield and productivity (Ingle et al., 2008; El-Shaikh and Mohammed, 2009; Mal et al., 2014) of okra through improvement of soil health and fertility in a sustainable manner (Sur and Das, 2006; Manivannan et al., 2009).

In addition to conventional fertilizers and organics, plant growth regulators (PGRs) often accelerate the growth and development of the plants. These PGRs, though often not given due importance, can ensure increase in dry weight, volume, size or shape of a cell of the plant. Optimum results were achieved in the desired direction through exogenous application of plant growth regulators to okra, either by seed treatment or by foliar spray. Increased seed germination (Mahesh and Sen, 2005), plant height, dry weight of plant, number of branches per plant, number of seeds per pod (Marie et al., 2007), plant growth and pod yield (Abdel Mouty and El-Greadly, 2008; Ayyub et al.,

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Table 1
Treatment combination of organic manure and inorganic fertilizer.

INM treatments administered	
T_1	RDF @ 120:60:50 (N:P:K) kg/ha
T_2	75% NP + full K + FYM @ 10 t/ha
T_3	75% NP + full K + Vermicompost @ 5 t/ha
T_4	75% NP + full K + *Azospirillum* + FYM @ 10 t/ha
T_5	75% NP + full K + PSB + FYM @ 10 t/ha
T_6	75% NP + full K + VAM + FYM @ 10 t/ha
T_7	75% NP + full K + *Azospirillum* + PSB + VAM + FYM @ 10 t/ha
GA levels applied	
GA_1	No GA applied
GA_2	GA applied @ 50 ppm at 21, 31, and 41 DAS

2013) of okra were obtained through use of PGRs like GA, NAA, etc.

To meet the requirement of the increased population, it would be necessary to raise vegetable production to 250 million tons by 2020 AD (Singh, 2000) under circumstances when per capita cultivable land is reducing, supposing to reach about 0.14 ha in 2025, compared with 0.17 ha at present (Kar, 2002). The vitamin- and mineral-rich okra is a prized vegetable in the Indian sub-continent. It has an average nutritive value of 3.21, which is higher than tomato, pumpkin and ash gourd (Grubben, 1977). Okra being a nutrient loving crop removes 0.30, 0.13 and 0.45 kg of N, P and K for 100 kg of pod yield and it responds well to added nutrient in soil (Hazra et al., 2011).

Proper nutrient management for increasing productivity and sustaining fertility may be explored to face the crisis ahead. Keeping this in consideration, the present investigation has been undertaken (i) to assess the efficiency of integrated nutrient management and application of growth regulators in improving okra yield and productivity and (ii) to explore the role of soil and plant nutrients in setting okra yield.

2. Materials and methods

2.1. Characterization of experimental site

Field experiments were conducted in an *inceptisol* with okra (cv. OH-152) at Central Research Farm, Bidhan Chandra Krishi Viswavidyalaya (Gayeshpur, Nadia, West Bengal; 23° N 89° E at 9.75 m above MSL) for two consecutive years. The experimental soils were non-saline (EC 0.285 dS/m), sandy-loam in texture, neutral in reaction (pH 6.9), low in organic carbon (4.2 g/kg), available N (138 kg/ha), high in available P (47 kg/ha) and medium in available K contents (130 kg/ha). The soils were low in DTPA extractable Fe, Mn, Cu and Zn (5.3, 4.2, 0.38 and 1.10 kg/ha, respectively). Average rainfall was 1500 mm and the climate was sub-tropical humid. Average maximum and minimum temperatures during cropping season of both the years remained within 12–36.5 °C.

The experiment was laid out in an asymmetric factorial design with seven different treatments of integrated nutrient management (INM) (T_1–T_7) and two levels of gibberellic acid (GA) (GA_1 and GA_2). Treatment details are presented in Table 1. Okra (*Abelmoschus esculentus* Moench) seeds were sown with a spacing of 60 × 45 cm on 3rd and 5th June 2011 and 2012, respectively. The unit plot size was 5 m × 2 m with 0.2 m bunds. Recommended dose of inorganic fertilizers @ 120:60:50 (N:P:K) kg/ha was applied. Urea, single super phosphate and muriate of potash (MoP) were used as source of N, P and K, respectively. The entire quantity of phosphorus, potassium and half of nitrogen were applied during final land preparation. Remaining N fertilizer was applied in two equal splits (one quarter each) at 30 DAS and at flowering, respectively. For uniform distribution of bio-fertilizer over the entire plot, each of *Azospirillum*, *Phosphate Solubilizing Bacteria* (PSB) and *Vesicular Arbuscular Mycorrhizal* (VAM) fungi was applied as a soil application @ 7.5 g along with 10 kg FYM and 5 kg vermicompost per plot in respective treatments before sowing. Okra pod was harvested following 9–10 pickings. The first picking was started at 40–45 days after sowing (DAS) and the consecutive pickings were done at 2–3 days interval during the peak fruiting stage.

2.2. Field observations

Plant height and basal girth were recorded at the time of final harvesting from fifteen randomly selected plants from each plot. Pod yield per plot was calculated by aggregating the data obtained from different harvesting dates, and the average pod yield was converted to tons per hectare (t/ha).

2.3. Analytical methodologies

The methods involved in analyses of soil (both initial and post-harvest) and plant samples are depicted in Table 2.

2.4. Statistical methodologies

The analysis of variance for different parameters of okra was done following the ANOVA technique and the mean values were adjudged by least significant difference (LSD) method. The best model for predicting yield from inputs (soil available nutrients and okra pod nutrient status) has been explored through artificial neural network (Chester, 1993) in *SPSS* 18.0.

The okra yield model shaping up through an improved soil and plant nutrient scenario under integrated nutrient management has been conceptualized through artificial neural network. Empirical methods for estimation of yield are often complex and unsteady. To derive accurate physical meaning involved, use of data mining techniques such as artificial neural network (ANN) is a new trend (Nourani and Fard, 2012). Nowadays, ANNs are being widely used in different sectors of agriculture like energy and greenhouse gas (GHG) emission, agricultural economics, agro-climatology, etc. Nourani and Fard (2012) used ANN in simulation of the evaporation process at different climatological regimes. Zangeneh et al. (2011) compared results of two different methods (parametric and ANN models) for evaluating economical indices of potato production such as economic productivity, total cost of production and benefit: cost ratio. In present study, we used ANN to predict the okra yield on the basis of soil available nutrients and okra pod nutrient concentration. Perhaps no research works have been done previously on the said arena.

The ANN, without considering any initial supposition and previous knowledge of relations among studied parameters, is able to find existed relation between input and output data to predict each output with its corresponding input. Hence for predicting the okra production on the basis of available soil nutrient status and concomitant plant nutrient concentration, we used the ANN method. In the present study, soil organic matter, soil available and okra pod concentration of macro (N, P and K) and micro nutrients (Fe, Mn, Zn and Cu) were considered as inputs of the model and okra yield as the output of the model. To ascertain the authenticity of the inputs of the model, correlations among different variables were drawn. Variables with low and insignificant correlation were chosen as inputs of the model. Multilayer perceptron (MLP) networks with various numbers of layers and neurons in each layer were employed to predict okra yield. As driving function for hidden and output layer, hyperbolic tangent and sigmoid functions were used in different combinations.

For hidden node determination, two thumb rules were followed: (1) number of hidden neuron should fall within number of input neurons and number of output neuron (Sheela and Deepa, 2013; Blum, 1992), and (2) it should never be more than twice as large