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BIOINOCULATION AND CHEMICAL FERTILIZATION EFFECT ON DRY MATTER PRODUCTION, NUTRIENT UPTAKE AND POST-HARVEST SOIL PROPERTIES IN POINTED GOURD (*Trichosanthes dioica* Roxb.)

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Abstract- A field experiment on combined use of bioinoculation and chemical fertilizer was conducted with test crop pointed gourd *cv.* Swarna Alaukik consecutively during 2012-13 and 2013-14 rabi and summer seasons in the research plots of "Network Project on Biofertilizers", OUAT, Bhubaneswar. Integrated application of different levels of N, P and K with biofertilizers (Azotobacter sp., Azospirillum sp. and Phosphate Solubilising Bacteria [PSB] – Bacillus sp.), lime and organic manure significantly increased the dry matter contents *viz.*, fruit, vine and total dry weight of pointed gourd fruit. Likewise, maximum crop nutrient uptake (N, P and K) and post harvest soil nutrient (N, P and K) availability were recorded in the treatment T12 [Lime + Biofertilizer + Vermicompost @ 5 t ha-1 + RDF (100%)]. Investigation leads to conclude that, the liming plots positively influenced the post harvest soil microbial biomass compared to unlimed plots which in turn directly influenced the crop nutrient uptake (N- 44.26%, P- 119.97% and K- 35.79%) as well as post crop soil health leading to sustainable cultivation practice.

Keywords- INM, nutrient uptake, microbial parameters, dry matter, pointed gourd

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Introduction

Pointed gourd (*Trichosanthes dioica*) is a tropical vegetable crop having Indian subcontinent origin. It is known by the name of potal in different parts of Bangladesh and as Parwal is a very important vegetable in India and Pakistan. It is very popular in Bengal, Assam, Odisha, Uttar Pradesh and Bihar. The crop belongs to family- Cucurbitaceae having 110 genera and 640 species [1]. The most important genera are *Cucurbita, Cucumis, Ecballium, Citrullus, Luffa, Bryonia, Momordica, Trichosanthes*, etc. *Trichosanthes* is an annual or perennial herb distributed in tropical Asia, Polynesia, and Australia. Over 20 species are recorded in India of which two, namely *T. anguina and T. dioica*, are cultivated as vegetable.

Productivity constraint of pointed gourd is mainly associated with poor nutrient management. Soil has limited nutrient supply; therefore, it has to be boosted with some external nutrient for proper growth and development of crop. Continuous and imbalanced use of fertilizers is negatively affecting the sustainability of crop production and simultaneously disturbing the soil environment. On the contrary, practice of INM not only maintains soil fertility and optimum supply of plant nutrients but is a reliable way of achieving fertilizer economy [2]. Addition of organic manure and biofertilizers benefit soil by increasing the population of microorganisms especially in the surface layer-root rhizosphere that produce substances, which stimulate plant growth. The usage of such organic sources help to maintain soil organic matter content, influence soil micro flora, plant growth and also provide growth regulatory substances [3]. Keeping above in view the present study has been conceptualized to assess the effects on nutrient uptake by pointed gourd owing to integration of bioinoculation with chemical fertilizers, also the influence on post-harvest soil properties**.**

Materials and Methods

Field experiments were undertaken consecutively during 2012-13 and 2013-14 rabi and summer seasons in the research plots of the project "Network Project on Biofertilizers", College of Agriculture, OUAT, Bhubaneswar located on 22^{0}15' North latitude, 80^{0}22' East longitude and 25.5 m above sea level. The place is characterized by warm and moist climate with hot and humid summer and mild winter.

The experiment included application of inorganic fertilizers (Urea- 90 kg ha^{-1}, Diammonium Phosphate- 60 kg ha^{-1} and Muriate of potash- 60 kg ha^{-1}), organic manure (vermicompost), biofertilizers (*Azotobacter sp., Azospirillum sp.* and Phosphate Solubilising Bacteria [PSB] – *Bacillus sp.*) and lime (Paper Mill Sludge) in various combinations of nutrient management as mentioned in [Tables 2-5] to test crop pointed gourd *cv.* Swarna Alaukik,. The treatments were replicated thrice in randomized block design (RBD). Pointed gourd root cuttings were planted at a spacing of 1.2 x 1.2 m in plots of 3.6 × 3.6 m^2 size. Normal cultural practices and plant protection measures were followed during the crop growth period to raise a quality crop. The experiment was conducted consecutively for two years i.e. 2012-13 and 2013-14 on the same experimental plot with sandy loam soil, acidic pH and low organic carbon [Table-1].

Two plants were selected at random from each plot of each treatment as representative sample for recording the data. The pooled mean values of each treatment in each replication for individual observation were calculated. Data were tabulated and subjected to statistical analysis using SAS 9.3. All data were subjected to analysis of variance. Comparisons of means were made by Duncan's multiple range test ($P \le 0.01$).

Results and Discussion

Dry matter content

The dry matter content *viz.,* fruit, vine and total dry weight were recorded maximum in T_{12} (8.77 q ha^{-1}, 12.80 q ha^{-1} and 21.40 q ha^{-1}) over rest of the treatments followed by T_{11} and T_{10} [Table-2]. The fruit dry weight was at par in T_{11} and T_{10} but the vine weight and total dry weight were significantly higher in plots receiving lime, RDF along with vermicompost (T_{11}). Further, with respect to dry matter contents, no significant differences were observed between the treatments T_5 (75% RDF) and T_9 (Lime + BF + VC@2.5 t ha^{-1}). The variation in dry weights and leaf area of the studied pointed gourd cuttings treated with different nutrient sources may be due to higher availability and increased uptake by the pointed gourd cuttings [12]. Since N played major roles in the synthesis of structural proteins and other several macro-molecules in addition to its vital contribution towards several biochemical processes in the plant related growth [13]. The increase in dry weight of different plant organs of pointed gourd were directly related to increase in vegetative growth in different treatments [14]

Table-1 *Physico-chemical and microbial properties of the initial soil of the experimental site*

Soil Properties	Year 2012-13	Year 2013-14	Methods Adopted	Reference
Sand (%)	75.6	72	Bouyocous Hydrometer method	[4]
Silt (%)	14.4	16		
Clay (%)	10	12		
Textural class	Sandy loam	Sandy loam	International triangle method	[5]
Bulk density (Mg m^{-3})	1.64	1.67	Core sampling method	[6]
pH (1: 2.5)	4.62 (low)	4.73 (low)	Beckman's electronic pH meter	[7]
Organic carbon (%)	0.39 (low)	0.43 (low)	Walkley and Black wet oxidation method	[8]
Available N (kg ha^{-1})	272.0 (medium)	263.0 (medium)	Alkaline potassium permanganate method	[9]
Available P (kg ha^{-1})	27.00 (medium)	28.35 (medium)	Bray's-1 extracting method	[8]
Available K (kg ha^{-1})	214 (medium)	226.21 (medium)	Ammonium acetate extracting method	[7]
Mean Total Heterotrophic Bacteria (CFU X 10^4 g^{-1} soil)	32	39	Serial Dilution and Spread Plate Technique	[10]
Mean Actinomycetes population (CFU X 10^4 g^{-1} soil)	40	35	Serial Dilution and Spread Plate Technique	[10]
Microbial biomass carbon (µg C g^{-1} soil)	34.26	42.30	Chloroform Fumigation Method	[11]

Table-2 *Dry matter content of pointed gourd plant as influenced by integrated nutrient management (pooled over 2012-2013 and 2013-2014)*

Treatments	Fruit Dry weight (q ha^{-1})	Vine Dry weight (q ha^{-1})	Total Dry weight (q ha^{-1})
T_1- Control (only FYM)	7.06i	8.48j	15.53j
T_2- Lime as PMS @ 5 t ha^{-1}	7.75fg	10.58g	18.32g
T_3- Biofertilizers (*Azotobacter sp.* + *Azospirillum sp.* + *Bacillus sp.*)	7.43h	9.11i	16.54i
T_4- Vermicompost @ 5 t ha^{-1}	7.62g	9.67h	17.29h
T_5- Recommended Dose of Fertilizer (75%)	8.11d	11.18e	19.29e
T_6- Lime + Biofertilizer	7.83ef	10.64g	18.47g
T_7- Lime + Vermicompost @ 2.5 t ha^{-1}	7.91e	10.89f	18.80f
T_8- Lime + RDF (75%)	8.34c	11.66d	20.00d
T_9- Lime + Biofertilizer + Vermicompost @ 2.5 t ha^{-1}	8.14d	11.31e	19.45e
T_{10}- Lime + Biofertilizer + RDF (75%)	8.50b	11.88c	20.38c
T_{11}- Lime + Vermicompost @ 5 t ha^{-1} + RDF (75%)	8.60b	12.13b	20.73b
T_{12}- Lime + Biofertilizer + Vermicompost @ 5 t ha^{-1} + RDF (100%)	8.77a	12.80a	21.40a
CV (%)	1.075	0.993	0.566

* PMS- Paper Mill Sludge

Nutrient uptake

Pointed gourd removed good quantity of N (27.24 – 65.77 kg ha^{-1}), P (9.11 – 51.27 kg ha^{-1}) and K (26.02 – 53. 83 kg ha^{-1}) from soil. Highest amount of N, P and K uptake [Table-3] was observed in crops amended with 100 % NPK of recommended dose through chemical fertilizers along with biofertilizers, vermicompost and lime (T_{12}). This might be due to the favourable effect of inorganic, organic and biological sources for increasing the total uptake of N, P and K causing enhancement of plant growth parameters and dry weight per hectare and higher N, P and K concentration in different plant organs (fruit and vine) and this in turn increased total uptake of N, P and K by pointed gourd plant. The treatments T_5 (75% RDF) and T_9 (Lime + BF + VC@2.5 t ha^{-1}) were at par with respect to N uptake, but plants treated with lime, biofertilizers and organics recorded significantly higher P and K uptake over T_5 (75% RDF). Increased nitrogen uptake by the combined use of organic and inorganic fertilizers has been reported earlier in pea [15 & 16]. The integrated applications of chemical fertilizers and organic manures improve the soil structure, create better environment for root development and increase water holding capacity, thereby reducing soil erosion, enhancing utilization and uptake of nutrients and also encourage soil micro-organisms, leading to N-fixation and mobilization. Addition of biofertilizers and organic manures might have created favourable environment in the rhizosphere for continuous uptake of nutrients. The above nutrients were available to the crop immediately from the inorganic source and afterwards through mineralization of organic matter without any loss, supplemented the availability.

Table-3 *Total Nutrient uptake by pointed gourd plant (vine + fruit) as influenced by integrated nutrient management (pooled over 2012-2013 and 2013-2014)*

Treatments	Total N Uptake (kg ha^{-1})	Total P Uptake (kg ha^{-1})	Total K Uptake (kg ha^{-1})
T_1- Control (only FYM)	27.24k	9.11l	26.02l
T_2- Lime as PMS @ 5 t ha^{-1}	40.78h	16.19i	34.72i
T_3- Biofertilizers (*Azotobacter sp. + Azospirillum sp. + Bacillus sp.*)	32.18j	10.59k	29.47k
T_4- Vermicompost @ 5 t ha^{-1}	36.93i	12.03j	31.38j
T_5- Recommended Dose of Fertilizer (75%)	49.75e	28.77f	39.88f
T_6- Lime + Biofertilizer	42.90g	20.50h	35.89h
T_7- Lime + Vermicompost @ 2.5 t ha^{-1}	47.45f	24.46g	37.43g
T_8- Lime + RDF (75%)	55.24d	35.42d	44.69d
T_9- Lime + Biofertilizer + Vermicompost @ 2.5 t ha^{-1}	51.02e	32.30e	41.38e
T_{10}- Lime + Biofertilizer + RDF (75%)	57.62c	40.39c	47.19c
T_{11}- Lime + Vermicompost @ 5 t ha^{-1} + RDF (75%)	60.85b	45.57b	49.07b
T_{12}- Lime + Biofertilizer + Vermicompost @ 5 t ha^{-1} + RDF (100%)	65.77a	51.27a	53.83a
CV (%)	1.92	2.25	1.27

* PMS- Paper Mill Sludge

Available Nitrogen

Significantly higher post-harvest availability of N in the soil was recorded in plots with integrated application of 100 % recommended dose of fertilizer, mixed biofertilizers along with vermicompost and lime as compared to sole application of inorganics and control [Table-4]. This might be due to direct addition of the N through organic manures to the available N pool of the soil. The decomposition and/or mineralization of organic manures are accompanied by the release of appreciable quantities of carbon dioxide, which when dissolved in the water forms carbonic acid capable of weathering certain primary minerals. Moreover, the organic matter supplied through organic manures might have helped in the greater multiplication of microbes for the conversion of organically bound N to inorganic forms. Thus, the residual effects of organic manure might be ascribed to the improved N availability and use efficiency. Increased N availability by addition of organic manures (cow dung manure, neem cake and vermicompost) has been reported earlier in bell pepper [17,18].

The treatment T_9 (Lime + BF + VC@2.5 t ha^{-1}) recorded significantly higher post harvest available N over T_5 (75% RDF). The increase in available nitrogen content of soil might be due to the combined effect of nitrogen fixing bacteria (*Azotobacter sp., Azospirillum sp.*) and vermicompost. On the other hand, significantly lower availability of N may be due to sole application of inorganic fertilizers experiencing rapid leaching, volatilization, immobilization and fixation of inorganic portion of N. The organic carbon in vermicompost releases nutrients slowly and steadily into the soil and enables the plants to absorb the available nutrients [19,20,21]. Application of organic fertilizers has an emphatic effect on plant growth and production [21].

Available Phosphorous

The status of soil phosphorus improved initially due to direct application of phosphorus to soil, and then through the microbes capable of solubilizing soil phosphorus. It is seen from the results that due to different treatments (T_2 to T_{12}); there is a significant increase in available P status as compared to the control (T_1). However, the values declined across all the treatments as compared to initial soil phosphorus status in the control. Combined application of lime, biofertilizer, vermicompost and RDF (100%) recorded significantly higher available P over rest of the treatments imposed. Application of organic manures significantly reduced the fixation of added as well as native P, making more P available to the plants. Significantly higher available P was recorded in T_9 (Lime + BF + VC@2.5 t ha^{-1}) compared to T_5 (75% RDF). Addition of organic manures and biofertilizers, especially PSB (*Bacillus sp.*) increased the solubility of phosphorus by producing certain organic acids and thereby increased the soil available phosphorus [18]. Significantly, higher available P in soil with higher fertilizer doses compared to application of lower level of fertilization or with no soil amendments is probably due to higher residual effects of both organic manures and biofertilizers for release of unavailable P form to available form. Significant increase in phosphate in the soil by the application of vermicompost in combination with biofertilizer and chemical fertilizers might be due to the presence of phosphate solubilizing bacteria, which increase the available phosphorous content of the soil. Likewise, the available phosphorus content of soil was improved significantly in the plots treated with inoculation of PSB over non-inoculated plot which may be attributed to the solubilization of insoluble phosphate into available phosphate in soil by PSB. P content can be attributed to the increased activity of micro-organisms because of the application of organic manures [22] and also had solubilizing effect on fixed and unavailable form of nutrients in the soil [3,23].

Available Potassium

Significantly higher available K was recorded in plots receiving 100 % recommended dose of fertilizer, bio-fertilizer, vermicompost and lime (T_{12}) followed by T_{11} and T_{10}. Increase in available potassium (K) due to vermicompost and biofertilizer might be attributed to the direct addition of potash to the available pool of the soil. The organic component of the treatments increased potassium availability in soil which could be attributed to the greater capacity of organic colloids to hold K ions on the exchange sites. The build up of available K might be due to the beneficial effects of organic manures on the reduction in K-fixation, release of K due to the interactions of organic matter with clay and direct addition of K upon decomposition of organic manures in field pea [24,25].

Table-4 *Effect of integrated nutrient management on post-harvest soil available N, P and K (pooled over 2012-2013 and 2013-2014)*

Treatments	AVAILABLE N (kg ha^{-1})	AVAILABLE P (kg ha^{-1})	AVAILABLE K (kg ha^{-1})
T_1- Control (only FYM)	235.35l	16.45i	199.60l
T_2- Lime as PMS @ 5 t ha^{-1}	251.62i	20.13gh	220.64i
T_3- Biofertilizers (*Azotobacter sp.* + *Azospirillum sp.* + *Bacillus sp.*)	240.69k	18.20hi	201.95k
T_4- Vermicompost @ 5 t ha^{-1}	248.08j	21.43g	212.86j
T_5- Recommended Dose of Fertilizer (75%)	277.49f	32.72de	245.45f
T_6- Lime + Biofertilizer	257.84h	27.71f	227.82h
T_7- Lime + Vermicompost @ 2.5 t ha^{-1}	272.67g	31.66e	243.29g
T_8- Lime + RDF (75%)	338.86d	36.60c	259.49d
T_9- Lime + Biofertilizer + Vermicompost @ 2.5 t ha^{-1}	312.55e	34.14d	255.33e
T_{10}- Lime + Biofertilizer + RDF (75%)	350.37c	37.80c	262.49c
T_{11}- Lime + Vermicompost @ 5 t ha^{-1} + RDF (75%)	358.27b	44.41b	264.24b
T_{12}- Lime + Biofertilizer + Vermicompost @ 5 t ha^{-1} + RDF (100%)	376.52a	51.19a	268.02a
CV (%)	0.56	3.99	0.42

* PMS- Paper Mill Sludge

Microbial biomass

Soil microbial biomass carbon (MBC) and the population dynamics of total heterotrophic bacteria and actinomycetes were significantly affected by integrated nutrient management practices. Application of lime positively influenced the microbial biomass in both the year 2012-13 and 2013-14 [Table-5]. Significantly highest values of total heterotrophic bacteria, actinomycetes population and MBC values were recorded in the plots amended with recommended dose, biofertilizers, vermicompost and lime (T_{12}) over rest of the treatments in both the cropping years, indicating higher rhizospheric activity. Combined application of bio-fertilizers with chemical fertilizer and organic manures improved the soil microbial population [26,27,28]. Liming the soil in conjunction with organic application positively influenced the soil MBC values in the post harvest soil over sole application of inorganics and unlimed plots. Further, among the unlimed plots, the plots receiving sole application of vermicompost (@5 t ha^{-1}) (T_4) recorded significantly higher microbial activity compared to the plots treated with RDF (75%).

Table-5 *Microbial parameters as influenced by integrated nutrient management in pointed gourd*

Treatments	Mean Total Heterotrophic Bacteria X 10^4 CFU g^{-1} soil		Mean Actinomycetes population X 10^4 CFU g^{-1} soil		Microbial biomass carbon (MBC) µg C g^{-1} soil	
	2012-13	2014-15	2012-13	2014-15	2012-13	2014-15
T_1- Control (only FYM)	39h	43j	42j	41h	37.60k	46.35k
T_2- Lime as PMS @ 5 t ha^{-1}	46fg	47ij	53hi	66fg	76.32i	82.60i
T_3- Biofertilizers (*Azotobacter sp.* + *Azospirillum sp.* + *Bacillus sp.*)	51ef	49hi	56h	54g	116.23h	109.29h
T_4- Vermicompost @ 5 t ha^{-1}	56e	58g	109e	113d	131.32g	131.40g
T_5- Recommended Dose of Fertilizer (75%)	41gh	36j	46ij	58g	74.56j	72.39j
T_6- Lime + Biofertilizer	76d	69f	83f	96e	154.53f	147.31f
T_7- Lime + Vermicompost @ 2.5 t ha^{-1}	82d	79e	116de	123d	163.65e	160.32e
T_8- Lime + RDF (75%)	52ef	55gh	64g	72f	120.36g	123.10g
T_9- Lime + Biofertilizer + Vermicompost @ 2.5 t ha^{-1}	96c	93d	121d	152c	189.63d	202.65c
T_{10}- Lime + Biofertilizer + RDF (75%)	116b	107c	136c	141c	219.74c	183.45d
T_{11}- Lime + Vermicompost @ 5 t ha^{-1} + RDF (75%)	112b	119b	153b	173b	226.50b	224.00b
T_{12}- Lime + Biofertilizer + Vermicompost @ 5 t ha^{-1} + RDF (100%)	132a	137a	162a	186a	246.62a	236.50a
CV (%)	5.18	6.83	4.53	6.47	4.83	3.80

* PMS- Paper Mill Sludge

Conclusion

Soil amelioration with paper mill sludge(PMS) and application of inorganic as well as organic fertilizers enhanced the bioavailability and mobility of plant nutrients and improved the rhizospheric microbial activity of the crop which in turn positively influenced the dry matter contents and nutrient concentrations in the pointed gourd. However, use of organics alone particularly in high productive crops like vegetables failed to sustain optimum yield. Integrated nutrient management not only improved the dry matter yields but also the quality and nutrient status of soil.

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