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INTEGRATED NUTRIENT MANAGEMENT STUDIES ON BIOMASS, DYE YIELD AND QUALITY OF INDIGO (*INDIGOFERA TINCTORIA* L.)

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Abstract

Field experiment was conducted to study the influence of integrated nutrient management with 25, 50, 75 and 100 per cent of inorganic combination (OD - Optimal dosage i.e., N_{20} P_{60}) with Vermicompost @ 5 t ha^{-1} + Bio-fertilizer consortium @ 5 kg ha^{-1}) was studied with seven treatments. The experiment was laid out in randomized block design with three replications. The following biometric observations *viz*., plant height (cm), plant spread (cm), number of branches, number of leaves, leaf area (cm^2), biomass (g $plant^{-1}$), fresh weight of shoots (g $plant^{-1}$), fresh weight of leaves (g $plant^{-1}$), glucoside content (%), indigo content dye yield and dye recovery were recorded at 160 days after sowing. From the experiment, it was found that the treatment, T_5 (Vermicompost @ 5 t ha^{-1} + Bio-fertilizer consortium @ 5 kg ha^{-1}) + 75 % OD (N @ 15 kg $ha^{-1}$and P @ 45 kg ha^{-1}) registered the highest dye yield and indigo content.

Keywords **:** Indigo, Integrated nutrient management, glucoside content, indigo content

Introduction

Natural dyes have been used since ancient times for colouring and printing fabrics. Until the middle of last century, most of the dyes were derived from plant or animal sources by long and elaborate processes. With the introduction of synthetic dyes for most of the traditional colours, including blue in the nineteenth century A.D., natural dye has gradually gone out of existence from most parts of the country. Almost all the synthetic dyes have their origin from coal tar and many synthetic dyes may lead to various harmful by-products during their manufacture. A number of azo dyes, which release carcinogenic harmful amines, have already been banned by most of the countries (Kumar *et al.,* 2007). Natural dyes offers an important alternative in these regards, as these are safer in use with minimum health hazards, have easy disposability, are biodegradable. Due to environmental awareness, the natural dyes obtained from plant and animal sources are recommended as the dyes of 21st century. Now, interest in natural dyestuffs has revived, not only in India but also in Europe, Japan and the United States. A variety of plants have provided indigo throughout history, but most natural indigo was obtained from those in the genus *Indigofera*, which are native to the tropics. In temperate climates, indigo can also be obtained from Woad (*Isatis tinctoria*) and Dyers knot weed (*Polygonum tinctorium*). Regardless of its origin, all indigo has the same chemical structure. Among the various indigo yielding plants, indigo from *Indigofera tinctoria* obtained from tropical regions is in good demand. Though this crop is not new to India, the traditional knowledge on the cultivation has almost disappeared due to the synthetic dyestuff. Anbalagan (2005) reported that in Tamil Nadu, to revive this dye plant cultivation into an economically viable industry, efforts are to be made to increase the yield of dye and quality.

Indigofera tinctoria bears the common name true indigo, *avuri / neel* in Tamil, *neelyamari* in Malayalam, *Indian indigo* in English and *neelini / neelika / nenjini* in Sanskrit is a commercial as well as medicinally useful leguminous plant. True indigo, is a shrub one to two meters height. It may be annual, biennial, or perennial, depending on the climate in which it is grown. It has light green pinnate leaves and pink or violet flowers. The plant is a legume, so it is rotated into fields to improve the soil in the same way that other legume crops such as alfalfa and sesbania exploitation (Angelini *et al*., 2003).

The dye is obtained from the processing of the entire herbage above ground. They are soaked in water and fermented in order to convert the glucoside (*indican*) naturally present in the plant to the blue dye (indigotin). Issues related to the organic or inorganic nutrients needs special attention in developing eco-technology for the production of natural dye crops which is demanded by eco-textile industries. Presently the opinion differs over going for completely organic or inorganic. However, the integration of inorganic fertilizers with organic manures is found viable and further reduced to a level which is economical and eco-friendly. With this idea in mind an integrated nutrient management treatments were tried.

Materials and Methods

Field experiment was conducted to study the influence of integrated nutrient management with 25, 50, 75 and 100 per cent of inorganic combination (OD - Optimal dosage i.e., N_{20} P_{60}) with Vermicompost @ 5 t ha^{-1} + Bio-fertilizer consortium @ 5 kg ha^{-1}) was studied with seven treatments. The plants of each accession were raised in plots of size of 6 x 4 m by sowing the seeds in lines at a spacing of 90 x 90 cm. The experiment was laid out in randomized block design with three replications. The following biometric observations *viz*., plant height (cm), plant spread (cm), number of branches, number of leaves, leaf area (cm^2), biomass (g $plant^{-1}$), fresh weight of shoots (g $plant^{-1}$), fresh weight of leaves (g $plant^{-1}$), glucoside content (%), indigo content dye yield and dye recovery were recorded at 160 days after sowing.

Results and Discussion

Among the treatments, the highest plant height (212.7 cm), maximum plant spread (171.8 cm), maximum number of branches (189.2), maximum number of leaves (2712.6), largest leaf area (23.16 cm^2), maximum bio-mass of 920.5 g $plant^{-1}$ was recorded in T_4 (Vermicompost @ 5 t ha^{-1} + Bio-fertilizer consortium @ 5 kg ha^{-1}) + 100 % OD (N @ 20 kg ha^{-1} and P @ 60 kg ha^{-1}) which was significantly higher than T_5 (Vermicompost @ 5 t ha^{-1} + Bio-fertilizer consortium @ 5 kg ha^{-1}) + 75 % OD (N @ 15 kg ha^{-1} and P @ 45 kg ha^{-1}). However, the least plant height (103.1cm), least plant spread (78.8), least number of branches (72.6), least number of leaves (1684.2), smallest leaf (19.01 cm^2) and least bio-mass of 519.3 g plant $^{-1}$ was observed in T_1 (Absolute Control)(Table.1.).

Among the treatments, the maximum fresh weight of shoot (826.6 g plant^{-1}) and maximum fresh weight of leaves of 425.6 g plant^{-1} was observed in T_4 (Vermicompost @ 5 t ha^{-1} + Bio-fertilizer consortium @ 5 kg ha^{-1}) + 100 % OD (N @ 20 kg ha^{-1} and P@ 60 kg ha^{-1}). It was statistically superior to T_5 (Vermicompost @ 5 t ha^{-1} + Bio-fertilizer consortium @ 5 kg ha^{-1}) + 75 % OD (N @ 15 kg ha^{-1} and P@ 45 kg ha^{-1}) which recorded a fresh weight of 818.6 g plant^{-1} and 392.6 g plant^{-1} respectively. However, the lowest fresh weight of shoot (417.3 g plant^{-1}) and fresh weight of leaves (208.6 g plant $^{-1}$) was observed in T_1 (Absolute Control).

Integrated nutrient management treatments significantly enhanced the glucoside content when compared with control (Table 2.). It is interesting to note that the maximum glucoside content of 0.85 per cent, maximum dye yield of 206.0 kg ha $^{-1}$, maximum dye recovery of 2.04 per cent and maximum indigo content of 2.88 per cent was recorded in T_5 (Vermicompost @ 5 t ha^{-1} + Bio-fertilizer consortium @ 5 kg ha^{-1}) + 100 % OD (N @ 20 kg ha^{-1} and P @ 60 kg ha^{-1}) followed by T_4 (Vermicompost @ 5 t ha^{-1} + Bio-fertilizer consortium @ 5 kg ha^{-1}) + 100 % OD (N @ 15 kg ha^{-1} and P @ 45 kg ha^{-1}). However, the minimum glucoside content (0.53 per cent), minimum dye yield (79.6 kg ha^{-1}), least dye recovery (1.59 per cent) and lowest indigo content (2.48 per cent) was observed in T_1 (Absolute Control).

The glucoside being a secondary metabolite, increasing N beyond certain level (i.e) N_{20} might have entered into other side reaction than the biosynthesis. In addition, the increased N might have lead to negative impact on formation of the pigment. This was supported by Pratibha and Korwar (2005) in *Indigofera tinctoria*, Hartl and Vogl (2003) in *Polygonum tinctorium,* and Sales *et al.* (2006) in *Isatis tinctoria.*

The data on growth characters viz., plant height, number of branches, number lf leaves, biomass obtained in T_4 (vermicompost @ 5 t ha^{-1} + bio-fertilizer consortium @ 5 kg ha^{-1} + (N @ 20 kg ha^{-1} and P @ 60 kg ha^{-1}) could be attributed to the complementary effect of organic and inorganic nutrients. This treatment registered an increase of 5 per cent over the sole application of inorganic nutrients. Further, reducing the inorganic nutrient up to 50 per cent also showed an increased yield over the sole application. However, a gradual decrease in the yield at 75 % and 50 % level of inorganic dosage was noticed.

Even-though, the highest biomass was recorded at T_4 (vermicompost @ 5 t ha^{-1} + bio-fertilizer consortium @ 5 kg ha^{-1} + N @ 20 kg ha^{-1}and P @ 60 kg ha^{-1} (9.92 t ha^{-1}) the data on dye yield and quality gave a different picture. Hence, an analysis was done to find out the cause for the highest dye yield recorded at T_5 (Vermicompost @ 5 t ha^{-1} + Bio-fertilizer consortium @ 5 kg ha^{-1}) + 75 % OD (N @ 15 kg ha^{-1} and P @ 45 kg ha^{-1}).

The data on biomass and its partitioning into stem and leaves indicates that at 75% OD (N@ 15 kg ha^{-1} + P @ 45 kg ha^{-1} + (Vermicompost @ 5 t ha^{-1} + Bio-fertilizer consortium) there was equal partitioning towards stem and leaves, whereas at 100% OD, there was more partitioning towards stem rather than leaves, as the precursors are synthesized in the leaves and then translocated to the stem portion. Leaves contain more *indican* than stem, thus the high dye yield obtained in the best treatment might be attributed to more leaves and glucoside content.

From the experiment, it was concluded that, among the seven treatments, T_5 (Vermicompost @ 5 t ha^{-1} + Bio-fertilizer consortium @ 5 kg ha^{-1}) + 75 % OD (N @ 15 kg ha^{-1}and P @ 45 kg ha^{-1}) registered the highest dye yield and indigo content and it was followed by T_4 (Vermicompost @ 5 t ha^{-1} + Bio-fertilizer consortium @ 5 kg ha^{-1} + 100 % OD (N @ 20 kg ha^{-1}and P @ 60 kg ha^{-1}). These two were identified as the top two best treatments. Based on the yield and quality, application of five tonnes of vermicompost along with biofertilizer consortium @ 5 kg ha^{-1} and N @ 15 kg ha $^{-1}$ and P @ 45 kg ha^{-1} can be recommended for yield maximization.

Table 1 : Effect of integrated nutrient management on growth characters of Indigo (*Indigofera tinctoria* L.)

T.No	Treatment details	Plant height (cm)	Plant spread (cm)	Number of branches (plant^{-1})	Number of leaves (plant^{-1})	Leaf area (cm^2)	Bio-mass (g plant $^{-1}$)
T_1	Absolute control	103.1	78.8	72.6	1684.2	19.01	519.3
T_2	VC @ 5 t ha^{-1} + BF-C @ 5 kg ha^{-1}	169.8	134.6	130.3	2351.8	22.19	751.4
T_3	100 % OD (N @ 20 kg ha^{-1} & P@ 60 kg ha^{-1})	192.2	157.4	156.3	2528.3	22.72	852.3
T_4	T_2 + 100 % OD (N @ 20 kg ha^{-1} & P@ 60 kg ha^{-1})	212.7	171.8	189.2	2712.6	23.16	920.5
T_5	T_2 + 75 % OD (N @ 15 kg ha^{-1} & P@ 45 kg ha^{-1})	204.2	166.4	174.6	2634.4	23.07	903.7
T_6	T_2 + 50 % OD (N @ 10 kg ha^{-1} & P@ 30 kg ha^{-1})	199.7	162.3	168.7	2597.7	22.95	881.3
T_7	T_2 + 25 % OD (N @ 5 kg ha^{-1} & P@ 15 kg ha^{-1})	183.3	149.5	142.5	2471.5	22.54	806.8
	S.Ed.	0.3	0.3	0.4	16.7	0.05	2.3
	CD (p = 0.05)	0.6	0.6	0.8	36.5	0.11	5.1

Table 2 : Effect of integrated nutrient management on yield characters of Indigo (*Indigofera tinctoria* L.)

T. No	Treatment details	Fresh weight of shoot (g plant^{-1})	Fresh weight of leaves (g plant $^{-1}$)	Glucoside content (%)	Dye yield (kg ha^{-1})	Dye recovery (%)	Indigo content (%)
T_1	Absolute control	417.3	208.6	0.53	79.6	1.59	2.48
T_2	VC @ 5 t ha^{-1} + BF-C @ 5 kg ha^{-1}	649.8	374.8	0.76	144.8	1.86	2.75
T_3	100 % OD (N @ 20 kg ha^{-1} & P@ 60 kg ha^{-1})	779.9	311.9	0.78	181.5	1.94	2.83
T_4	T_2 + 100 % OD (N @ 20 kg ha^{-1} & P@ 60 kg ha^{-1})	826.6	392.6	0.83	200.9	1.99	2.85
T_5	T_2 + 75 % OD (N @ 15 kg ha^{-1} & P@ 45 kg ha^{-1})	818.6	425.6	0.85	206.0	2.04	2.88
T_6	T_2 + 50 % OD (N @ 10 kg ha^{-1} & P@ 30 kg ha^{-1})	801.2	377.0	0.80	187.3	1.95	2.84
T_7	T_2 + 25 % OD (N @ 5 kg ha^{-1} & P@ 15 kg ha^{-1})	717.6	380.3	0.77	165..3	1.92	2.77
	S.Ed.	1.0	1.1	0.004	2.8	0.02	0.01
	CD (p = 0.05)	2.0	2.2	0.009	5.6	0.04	0.02

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