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Effect of Zinc Fertilization on the Growth, Yield and Nutrients Uptake by Bhendi in Coastal Sandy Soil

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Abstract **– A field experiment was carried out at farmer's field during July–October 2013, to study the effect of zinc fertilization on the growth, yield and nutrients uptake by bhendi in coastal soil. Texturally, the experimental soil was sandy and taxonomically classified as *Typic Usticpsamments* with initial soil characteristics (0-15 cm layer) of the experimental site were, pH–8.32 and EC–1.54 dS m^{-1}. The soil registered low organic carbon status of 2.30 g kg^{-1}, 134.50 kg ha^{-1} of alkaline $KMnO_4$–N; 9.48 kg ha^{-1} of Olsen–P and 178.20 kg ha^{-1} of NH_4OAc-K, respectively. The available DTPA extractable Zn content of 0.71 mg kg^{-1} in soil. The various treatments included were, T_1- Control (RDF alone), T_2 –RDF + Composted coirpith (CCP) @ 12.5 t ha^{-1}, T_3 –RDF + Zn humate Soil Application (SA) @ 30 kg ha^{-1}, T_4–RDF + Zn humate Foliar Application (FA) @ 0.5 per cent twice at 20 and 45 DAS, T_5 – RDF + CCP + Zn humate SA, T_6 – RDF + CCP + Zn humate FA and T_7 – RDF + CCP + Zn humate SA + FA. The above treatments were arranged in a Randomized Block Design (RBD) with three replications and tested with bhendi var. MBH 64 as test crop. The results of the study clearly showed that the yield benefit of the treatment Zn-humate @ 30 kg ha^{-1} through soil application + foliar spray @ 0.5 per cent twice at 20 and 45 DAS along with recommended dose of NPK and composted coirpith @ 12.5 t ha^{-1}superior in increasing the growth, yield and nutrient uptake by bhendi.**

Key words **– Zinc Humate, RDF, CCP, Soil Application, Foliar Application, Growth, Yield, Nutrient Uptake, Bhendi.**

I. INTRODUCTION

Vegetables are the storehouses of most of the vitamins, minerals and also proteins. The nutritional value of vegetables is unsurpassed many vegetables, have a low glycemic index and high nutrient content as compared to other foods. In majority of the coastal area, vegetable crops are cultivated in nutrient impoverished sandy soils. Among the vegetables, bhendi (*Abelmoschus esculentus* (L.) Moench.) is one of the major vegetable crops grown in almost all parts of the world. Bhendi fruits are rich in minerals, vitamins and essential amino acids; and provide valuable nutrient supplement in the tropical diet. India is the second largest producer of vegetables in the world (ranks next to china) and accounts for about 15 per cent of the world's production of vegetable (Soni *et al*., 2006).

In Tamil Nadu, the area under cultivation of bhendi is 3,417 hectares with a production of about 21,360 tonnes and productivity is 6.25 tonnes per hectare. Bhendi is one of the commonly grown vegetable crops in coastal areas of Tamil Nadu. The short duration, low cost of cultivation and regular income due to staggered harvesting attracted many farmers in this region to cultivate bhendi. However, the yield realized by the coastal farmers is around 2-3 t ha^{-1} which is very low and far below as compared to national average yield of around 6-9 t ha^{-1}. The reasons being, poor organic matter and micronutrient status of soil and adoption of traditional management practices. Hence, there is an imperative need to increase the production of vegetables by way of adopting some improved cultivation practices such as foliar feeding of nutrients and growth stimulants in addition to the basal application of nutrients. Foliar application of humic acids through zinc humate may solve the problem of assimilation of nutrients in the leaves, which resulted in an increased photosynthetic rate, better nutrient uptake from the soil and translocation of these nutrients from the leaves to fruits, thereby enhancing higher fruit yield. Further, foliar fertilization of nutrients to the plants helps to absorb and transport the nutrients without spending any energy as well as without any loss in transit (Srivastava, 1995). Hence, the present investigation was carried out to study the effect of zinc fertilization on the growth, yield and nutrients uptake by bhendi in coastal sandy soil.

II. MATERIALS AND METHODS

A field experiment was conducted in a farmer's field at Mandabam coastal village, near Chidambaram in Cuddalore district, Tamilnadu during July –October, 2013. The initial soil of the experimental site had a pH–8.32 and EC-1.54 d Sm^{-1}. The soil was low in organic carbon (2.30 g kg^{-1}), low in available N (134.50 kg ha^{-1}), available P (9.48 kg ha^{-1}) and medium in available K (178.20 kg ha^{-1}). The various treatments included were, T_1- Control (RDF alone), T_2 –RDF + Composted coirpith (CCP) @ 12.5 t ha^{-1}, T_3 –RDF + Zn humate Soil Application (SA) @ 30 kg ha^{-1}, T_4 –RDF + Zn humate Foliar Application (FA) @ 0.5 per cent twice at 20 and 45 DAS, T_5 – RDF + CCP + Zn humate SA, T_6 – RDF + CCP + Zn humate FA and T_7 – RDF + CCP + Zn humate SA + FA. The experiment was laid out in a Randomized Block Design (FRBD) with three replications, using bhendi var. MBH 64 as test crop. An uniform fertilizer dose of 40 kg of N + 50 kg of P_2O_5 + 30 kg of K_2O per hectare for bhendi was applied as urea, single super phosphate and muriate of potash, respectively. The entire dose of N, P_2O_5 and K_2O were applied as basal. Composted coirpith (CCP) @ 12.5 t ha^{-1} were applied basally and well incorporated into the soil in all the experimental plots. Required quantities of Zn Humate as per the treatment schedule were applied through soil as well as foliar. Foliar application of Zn Humate @ 0.5 per cent on 20 and 45 DAS was applied as per the treatment. Various growth components like plant height, number of branches $plant^{-1}$, dry matter production (DMP) and yield

components *viz.*, number of fruits plant^{-1}, fruit length and single fruit weight were recorded at harvest stage. The fruit and stover samples were collected at harvest stage and analysed for the content of N, P, K and Zn using the standard procedure as outlined by Jackson (1973) and uptake were calculated. At harvest fruit and stover yield were also recorded.

III. Results and Discussion

A. Growth Characters

The application of Zn significantly increased all the growth characters *viz.*, plant height, number of branches and dry matter production of bhendi. In coastal sandy soil the bhendi responded to Zn application upto 30 kg ha^{-1}. Among various treatments, the combined application of recommended dose of NPK + composted coirpith @ 12.5 t ha^{-1} + Zn-Humate @ 30 kg ha^{-1} through soil application along with foliar application of Zn-Humate @ 0.5 per cent twice at 20 and 45 DAS (T_7) produced the tallest plant height (136.51 cm), number of branches plant^{-1} (7.83) and dry matter production (12.91 t ha^{-1}) of bhendi. This was followed by the treatments T_5, RDF + CCP + Zn Humate (SA) through soil application (127.31cm, 7.25 and 12.13 t ha^{-1}), treatment T_6, RDF + CCP + Zn Humate (FA) foliar application @ 0.5% (118.62 cm, 6.63 and 11.32 t ha^{-1}), treatment T_3, RDF + Zn humate SA (109.27cm 6.10 and 10.62 t ha^{-1}) and treatment T_4, RDF + Zn humate FA (101.06 cm 5.65 and 9.83 t ha^{-1} plant height, number branches plant^{-1} and dry matter production, respectively). The control treatment (RDF alone) recorded the lowest growth characters viz., plant height, number of branches plant^{-1} and DMP of bhendi as compared to other treatments.

In coastal sandy soil, application of Zn-humate through soil application (SA) @ 30 kg ha^{-1} + foliar spray (FS) @ 0.5% at 20 and 45 DAS along with recommended dose of NPK and composted coirpith @ 12.5 t ha^{-1} recorded the highest plant height, number of branches plant^{-1} and dry matter production. This might be due to the increased nutrient supply with the addition of fertilizer and organics. Further, foliar spray of micronutrients might have induced the synthesis of chlorophyll content and direct effect of plant growth like auxin activity which in turn resulted in higher vegetative growth parameters *viz.*, plant height, number of branches and DMP. This present findings also are in conformity with earlier workers of Waskela *et al.* (2013) and Abbasi *et al.* (2010).

B. Yield characters

The application of Zn humate either through soil or foliage along with recommended dose of fertilizer (RDF) and CCP significantly and positively influenced the yield characters of bhendi. However, the combined addition of Zn by both soil and foliage recorded the better response in respect of yield characters than the sole application.

The highest number of fruits plant^{-1}, fruit length and single fruit weight was found with T_7, application of RDF + Zn Humate SA @ 30 kg ha^{-1} + Zn Humate FA @ 0.5 per cent along with CCP @ 12.5 t ha^{-1} which recorded 24.57 number of fruits plant^{-1}, 23.20 cm of fruit length and 28.40 g of single fruit weight, respectively. This was followed by the treatments T_5, RDF + CCP + Zn Humate SA (23.32, 21.94 cm and 26.62 g) treatment T_6, application of RDF + CCP + Zn Humate FA @ 0.5 per cent (21.79, 20.65 cm and 25.07 g of number of fruits plant^{-1}, fruit length and single fruit weight, respectively). The treatments supplied with RDF + Zn Humate through soil application @ 30 kg ha^{-1} (T_3) and RDF + Zn Humate through foliar @ 0.5 per cent (T_4) recorded a number of fruits plant^{-1} of 20.57 and 18.97 fruit length 19.33 and 17.92 cm and single fruit weight of 23.41 and 21.90 g of bhendi, respectively. The lowest number of fruits plant^{-1} (15.73), fruit length (14.74 cm) and single fruit weight (18.22 g) were recorded in control (T_1).

In promoting the over all yield attribute characters of bhendi, the addition of Zn-humate @ 30 kg ha^{-1} through soil + foliar spray twice @ 0.5% along with RDF + CCP out performed all other treatments. It is now well established that Zn a positive role in the fruit formation due to their involvement in the metabolism thereby increases the yield parameters. These results are line with (Datir *et al.*, 2010). In addition, foliar spray of Zn-humate @ 0.5% resulted in an increase in rhythm with the pattern of crop growth influenced the plant growth and yield attributing characters of bhendi. These results are in conformity with Yadav *et al.* (2007) and Sangeetha and Singaram (2007). High yield characters of bhendi might be attributed to increased dry matter accumulation in the reproductive parts and formation of higher sink capacity with the addition of NPK + Zn-humate. An adequate supply of plant nutrients enhanced the metabolic activity. Not only amount of nutrients present in soil but also their availability to meet out that needs of crop at critical growth stages resulted in increased plant growth and yield characters. These results are in agreement with Premsekhar and Rajashree (2009) and Akande *et al.* (2010).

C. Yield

The significant influence of zinc fertilization along with recommended NPK and CCP on fruit and stover yield of bhendi was well evidenced in the present study. The yield realised under the present field experiment confirmed the results of previous pot experiment. The highest fruit yield (15.94 t ha^{-1}) and stover yield (11.29 t ha^{-1}) was recorded with application of RDF (recommended dose of NPK) + CCP @ 12.5 t ha^{-1} along with Zn humate through soil application @ 30 kg ha^{-1} and foliar @ 0.5 per cent (T_7). This was followed by the treatments T_5, T_6, T_3, T_4 and T_2. The individual application of Zn-humate either through soil or foliar alone along with RDF and organics significantly increased the yield of bhendi as compared to control. Soil application of Zn humate @ 30 kg ha^{-1} along with RDF and organics (T_5) increased the fruit and stover yield to 14.98 and 10.43 t ha^{-1} respectively and foliar application of Zn humate @ 0.5 per cent along with RDF and organics (T_6) increased the fruit and stover yield to the tune of 14.16 and 9.73 t ha^{-1} respectively as compared to individual application of Zn humate through soil and foliar alone along with RDF.

Among the treatments, T_7 which received Zn humate through both the soil and foliage along with recommended dose of NPK and CCP recorded the higher fruit yield (15.94 t ha^{-1}) and stover yield (11.29 t ha^{-1}) as compared to control which recorded the 51.52 and 54.02 per cent yield increase over control. The favourable effect of Zn on fruit yield also could be attributed to their effect in maintaining soil available nutrients in balanced proportions for better growth in bhendi. The pronounced effect of Zn-humate foliar spray might be attributed to the beneficial role of Zn present in Zn-humate supplied through foliar spray might have helped in enhancing the enzyme and photosynthetic activities, accumulation of photosynthates thereby higher fruit yield. This findings corroborates the earlier report of Talukder *et al.* (1999) and Patel and Singh (2010).

The increase in fruit yieldmight be due to increased nutrients uptake from soil, effective utilization of foliar applied nutrients from Zn-humate, which resulted in better vegetative growth coupled with btter partitioning and promotion of photosynthesis and respiration contributed by the proteins and quinone groups, respectively of accumulated humic substances. The reports of Ertan Yildirim (2007) and Fathima and Denesh (2013) confirmed the present findings. The improvement in higher fruit and stover yield with foliar spray of Zn-humate and NPK fertilizer could be ascribed to the promoted cell division and cell elongation. Further, the humic acids are known form chelates with micronutrients like Zinc and thus it improves translocation of the nutrient cations within the plant system. The increased bhendi yield due to the application of humic acids and NPK fertilizer have already been well documented by Sangeetha and Singaram (2005) and Dhanasekaran and Bhuvaneswari (2005).

D. N, P, K and Zn nutrients uptake Nitrogen

The N uptake by bhendi at harvest stage in fruit and stover was significantly increased withthe zinc fertilization. Application of zinc as Zn humate either through soil or foliage and or both significantly increased the uptake of major nutrients by bhendi. Among the treatments evaluated, the combined application of Zn humate through soil and foliage along with recommended dose of NPK and organics recorded the highest N uptake by bhendi as compared to other treatments. The treatment T_7, recommended dose of NPK + CCP along with soil application of Zn humate @ 30 kg ha^{-1} and foliar spray @ 0.5 per cent ranked best and recorded the highest N uptake of 56.58 and 32.85 kg ha^{-1} by fruit and stover, respectively. This was followed by T_5, soil application of Zn humate @ 30 kg ha^{-1} T_6, foliar application of Zn humate @ 0.5 per cent along with RDF and CCP.

The treatment T_5, recorded a N uptake of 53.67 and31.16 kg ha^{-1} and treatment T_6, recorded a N uptake of 50.63 and 29.45 kg ha^{-1} by fruit and stover, respectively. The application of RDF + Zn humate SA (T_3) and RDF + Zn humate FA (T_4) treatments without organics recorded a lower N uptake by bhendi as compared to T_5 and T_6. Application of CCP along with RDF (T_2) received higher N uptake as compared to the treatment which received NPK alone (T_1). The lowest N uptake of 38.11 and 21.94 kg ha^{-1} by fruit and stover was noticed in control.

The N uptake was increased by combined application of NPK + Zn-SA @ 30 kg ha^{-1} and ZnFA @ 0.5% twice along with organics as compared to sole application of Zn either through soil or foliar. This is because of the fact that the micronutrient like zinc is involved in nitrogen fixation and translocation into plant parts, which might have increased the N content of plants. The higher nitrogen absorption may also be due to stimulatory effect of zinc on nitrogen uptake. In line with the present study, Jeanine *et al.* (2003) and Snajay Swami and Kapila Shekhawat (2009) also reported similar results.

Phosphorus

A significantly higher P uptake by bhendi was observed due to the zinc fertilization. Application of zinc along with either NPK alone or NPK + CCP favourably improved the uptake of phosphorus by bhendi. Mode of application had a significant difference in improving P uptake by bhendi. Soil application of Zn shared better response than foliar spray. Application of Zn through both soil and foliage recorded the highest response in response of P uptake by bhendi.

Application of Zn as zinc humate by both the modes *viz.*, soil (Zn humate @ 30 kg ha^{-1}) and foliar (Zn humate @ 0.5 %) along with CCP (T_7) accounted for the highest P uptake by bhendi in fruit and stover.

The highest phosphorus uptake of 16.08 kg ha^{-1} by fruit and 10.89 kg ha^{-1} by stover respectively were recorded with RDF (recommended NPK) + CCP along with soil application of Zn humate @ 30 kg ha^{-1} + foliar application of Zn humate @ 0.5 per cent (T_7). The single mode of application of Zn humate through soil alone or foliar alone along with NPK and organics significantly increased the P uptake as compared to NPK alone. This was followed by the treatments T_3, Zn humate SA and Zn humate FA (T_4) along with recommended NPK recorded a P uptake of 13.45 and 8.66 kg ha^{-1} and 12.46 and 7.75 kg ha^{-1} by fruit and stover, respectively. The control recorded the lowest P uptake (10.64 and 6.38 kg ha^{-1}) in fruit and stover, respectively as compared to treatment T_2, (11.67 kg ha^{-1} by fruit and 7.20 kg ha^{-1} in stover).

The addition of NPK fertilizers along with foliar spray of Zn-humate enhanced the uptake of NPK by bhendi. This might be due to increased availability of these nutrients released from applied fertilizers. Further, humic substances as zinc humate applied through foliage would have been easily absorbed and translocated in the plants without any loss which resulted in enhanced nutrients uptake by the crop. Similar findings were observed by Alexander and Schroeder (1987). The higher P content and uptake may be due to the solubilization of native phosphorus by the organic acids namely, lactic, glycolic, citric and succinic acid present in CCP. In addition, applied NPK resulted in better root growth and increased physiological activity of roots to absorb more phosphorus. These findings are in conformity with Akande *et al.* (2010) and Mehta *et al.* (2011).

Potassium

The uptake of potassium by bhendi fruit and stover was also significantly increased with zinc application. The application of RDF + CCP + Zn humate @ 30 kg ha^{-1} + Zn humate @ 0.5 per cent twice (T_7) registered the highest uptake of K by fruit and stover. It recorded a K uptake of 46.18 and 31.75 kg ha^{-1} by fruit and stover, respectively. This was followed by treatments T_5, application of RDF + CCP + Zn humate SA @ 30 kg ha^{-1} and T_6, application of RDF + CCP + Zn humate FA @ 0.5 per cent. The control treatment T_1, application of 100 per cent NPK alone (RDF alone) recorded a comparatively lower K uptake of 30.31 kg ha^{-1} by fruit and 21.03 kg ha^{-1} by stover as compared to application of RDF along with organics (T_2) which recorded a K uptake of 32.97 and 23.07 kg ha^{-1} by fruit and stover, respectively.

Increased K uptake might be due to better plant growth leading to higher uptake of nutrients and further on the stimulatory effect of Zn in absorption of potassium. These results are in accordance with the findings of Islam *et al.* (2011). The ready availability of K and other nutrients from inorganic sources produced adequate biomass which resulted in better nutrient uptake of the crop. These findings are in agreement with Singh *et al.* (2004). Further added organics improved the organic carbon content of soil through decomposition which helped in the release of organically bound macro and micronutrients in soil. In the overall improvement of NPK uptake with application of NPK, micronutrients and organics improved the plant growth and accumulation of greater biomass which helped to increased the uptake. Similar results of earlier reported by Punithraj *et al.* (2012).

Zinc uptake

The application of zinc humate either through soil or foliar along with NPK and composted coirpith had significant influence on zinc uptake by bhendi. Among the various treatments, the highest Zn uptake by fruit (123.00 g ha^{-1}) and stover (96.62 g ha^{-1}) was recorded with the application of recommended NPK + CCP @ 12.5 t ha^{-1} along with soil application of Zn humate @ 30 kg ha^{-1} and foliar spray @ 0.5 per cent (T_7). This was followed by the treatment supplied with RDF + CCP @ 12.5 t ha^{-1} + Zn humate SA @ 30 kg ha^{-1} (T_5) and the application of RDF + CCP @ 12.5 t ha^{-1} along with Zn humate FA @ 0.5 per cent (T_6). The treatments which received Zn humate through soil application (T_3) and foliar application (T_4) along with recommended NPK recorded a Zn uptake of 101.49 and 81.39 g ha^{-1} and 94.47 and 75.42 g ha^{-1} by fruit and stover, respectively. The control (RDF alone) registered the lowest Zn uptake (82.10 g ha^{-1} by fruit and 64.25 g ha^{-1} by stover) as compared to treatment T_2, application of RDF along with CCP (88.32 g ha^{-1} by fruit and 70.71 g ha^{-1} by stover).

The addition of Zn as Zn-humate though soil application and also the release of micronutrients from the added organics could have contributed for better availability Zn in rhizosphere. These results are in agreement with findings of the several researchers (Jeanine *et al.*, 2003 and Patel *et al.*, 2012) also recorded the highest uptake of micronutrients (Zn, Cu, Fe and Mn) with the combination of different zinc fertilizer and organic application.

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Table 1. Effect of Zn fertilization on the growth characters of bhendi

Treatments	Plant height (cm)	Number of branches plant^{-1}	Dry matter production (t ha^{-1})
T_1 – Control (RDF alone)	81.67	4.52	8.16
T_2 – RDF + CCP @ 12.5 t ha^{-1}	91.91	5.18	9.14
T_3 – RDF + Selected Zn Humate SA @ 30 kg ha^{-1}	109.27	6.10	10.62
T_4- RDF + Zn Huamte FA @ 0.5%	101.06	5.65	9.83
T_5 - RDF + CCP + Zn Humate SA	127.31	7.25	12.13
T_6 - RDF + CCP + Zn Humate FA	118.62	6.63	11.32
T_7 - RDF + CCP + Zn Humate SA + FA	136.51	7.83	12.91
SE_D	3.44	0.21	0.31
CD (p=0.05)	7.05	0.43	0.63

Table 2. Effect of Zn fertilization on the yield characters and yield of bhendi

Treatments	No. of fruits plant^{-1}	Fruit length (cm)	Single fruit weight (g)	Yield (t ha^{-1})	
				Fruit	Stover
T_1 – Control (RDF alone)	15.73	14.74	18.22	10.52	7.33
T_2 – RDF + CCP @ 12.5 t ha^{-1}	17.78	16.70	20.25	11.41	8.13
T_3 – RDF + Selected Zn Humate SA @ 30 kg ha^{-1}	20.57	19.33	23.41	13.22	8.87
T_4- RDF + Zn Huamte FA @ 0.5%	18.97	17.92	21.90	12.20	8.18
T_5 - RDF + CCP + Zn Humate SA	23.32	21.94	26.62	14.98	10.43
T_6 - RDF + CCP + Zn Humate FA	21.79	20.65	25.07	14.16	9.73
T_7 - RDF + CCP + Zn Humate SA + FA	24.57	23.20	28.40	15.94	11.29
SE_D	0.56	0.55	0.70	0.35	0.31
CD (p=0.05)	1.16	1.14	1.45	0.72	0.65

Table 3. Effect of Zn fertilization on the N, P, K (kg ha^{-1}) and Zn uptake (g ha^{-1}) by bhendi

Treatments	Nitrogen		Phosphorus		Potassium		Zinc	
	Fruit	Stover	Fruit	Stover	Fruit	Stover	Fruit	Stover
T_1 – Control (RDF alone)	38.11	21.94	10.64	6.38	30.31	21.03	82.10	64.25
T_2 – RDF + CCP @ 12.5 t ha^{-1}	41.36	24.00	11.67	7.20	32.97	23.07	88.32	70.71
T_3 – RDF + Selected Zn Humate SA @ 30 kg ha^{-1}	47.42	27.82	13.45	8.66	38.34	26.73	101.49	81.39
T_4- RDF + Zn Huamte FA @ 0.5%	44.47	25.89	12.46	7.75	35.47	24.98	94.47	75.42
T_5 - RDF + CCP + Zn Humate SA	53.67	31.16	15.22	10.26	43.57	30.13	114.47	91.88
T_6 - RDF + CCP + Zn Humate FA	50.63	29.45	14.40	9.48	41.02	28.59	108.15	86.85
T_7 - RDF + CCP + Zn Humate SA + FA	56.58	32.85	16.08	10.89	46.18	31.75	123.00	96.62
SE_D	1.32	0.75	0.36	0.25	1.18	0.73	2.86	2.26
CD (p=0.05)	2.71	1.55	0.74	0.52	2.42	1.50	5.85	4.62

*RDF- Recommended dose of fertilizer; CCP- Composted coirpith; SA- Soil Application; FA- Foliar Application