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Effect of split application of NPK along with basal dose of Zn and B on yield of sapota [*Manilkara achras* (Mill.) Forsberg] and soil properties

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Abstract
In order to understand the effect of split application of NPK along with basal dose of Zn and B on soil properties and on yield of sapota in lateritic soils of Konkan, an experiment in randomized block design with five treatments replicated four times was conducted at Department of Horticulture, College of Agriculture Dapoli, during June 2022 to May 2023 on thirty three years old sapota orchard of variety Kallipatti, where NPK @ 3:3:3 kg NPK each per tree were applied in two equal splits in June and September and in three equal splits in June, September and January along with basal application of vermicompost @ 50 kg per tree and $ZnSO_4$ @ 50 g per tree + Borax @ 25g per tree in June by ring method to the depth of 25-30 cm. The data revealed that the application 3 kg NPK each tree^{-1} in three equal splits in June, September and January with 50 kg Vermicompost and 50 g $ZnSO_4$ + 25 g Borax tree^{-1} in June was found to be significantly superior for enhancing the yield of sapota and the increase in soil pH, EC and organic carbon, available NPK, DTPA extractable Zn and available B indicating the built up of soil fertility in lateritic soils of Konkan.

Keywords: Sapota, split application, boron, zinc, fertilizers, vermicompost, lateritic soil

Introduction
Sapota, a native of Mexico belonging to family Sapotaceae, is a tropical fruit, yields fruit twice a year, though flowering may continue year-round and needs warm, humid climate for growth and development. Being a hardy crop, it can be grown on wide range of soil and climatic conditions (Dutton 1976) [6]. Sapota is mainly cultivated in India for its fruit value, while in South-east Mexico, Guatemala and other countries it is commercially grown for the production of gum like substance obtained from latex called chickle and is mainly used for preparation of chewing gum. Its fruits are round or oval, brown in outer appearance and very sweet in taste with almost no evident acidity.
In India there was production of 935.2 thousand MT of sapota from an area of 78.3 thousand ha and the productivity of 11.9 MT/ha. In Maharashtra it was grown under 12.80-thousand-hectare area with the production of sapota is 107.26 thousand MT with a productivity of 8.38 MT/ha (Anonymous, 2023) [1].
In Indian fruit orchards, poor soil health and imbalanced nutrient application are major causes of low orchard efficiency resulting in poor productivity. To optimize the fertilizer use, the approach of split application of fertilizer plays a very important role in a nutrient management strategy. Single application of fertilizer leads to period of over-supply, more leaching losses and also period of under-supply. It may not be able to maintain optimum soil nutrient status at all the critical growth stages of crop. So, it is paramount important to determine the number of splits for fertilizer application in sapota. Micronutrients can tremendously boost horticultural crop yield and improve quality and post-harvest life of horticultural produce (Raja, 2009) [12]. With this background, the present study was undertaken to standardize stage wise nutrient requirement in Sapota as well as requirement of Zn and B under Konkan conditions to achieve improved yield and soil properties in lateritic soils of Konkan.

Material and Methods

The experiment was conducted at nursery of Department of Horticulture, College of Agriculture Dapoli, during June 2022 to May 2023 on thirty-three years old sapota orchard of variety Kallipatti planted at spacing of 12.5m X 12.5m. The experiment was laid in RBD design comprising five treatments replicated four times *viz.* T_1- Absolute control (No fertilizer), T_2 -3 kg NPK each tree^{-1} in two equal splits in June and September and Vermicompost @ 50 kg tree^{-1} in June, T_3- 3 kg NPK each tree^{-1} in two equal splits in June and September and 50 g $ZnSO_4$ + 25 g Borax tree^{-1} in June and Vermicompost @ 50 kg tree^{-1} in June, T_4- 3 kg NPK each tree^{-1} in three equal splits in June, September and January and Vermicompost @ 50 kg tree^{-1} in June, T_5- 3 kg NPK each tree^{-1} in three equal splits in June, September and January and 50 g $ZnSO_4$ + 25 g Borax tree^{-1} in June and Vermicompost @ 50 kg tree^{-1} in June. Two trees were selected for each treatment. The split doses of fertilizers according to the treatment were mixed and applied in the ring dug to a depth of 25-30 cm covering the periphery of the plants and about 150 cm away from main trunk. The mature fruits were harvested with the help of Atul Sapota Harvester. The final yield per tree (kg) was obtained by sum of all the pickings. Treatment wise representative soil samples were collected from fertilizer ring of the tree at 30 cm depth from 4 spots at various stages *viz.*, at vegetative stage, at flowering stage and at harvesting of sapota. Available nitrogen was determined by alkaline permanganate (0.32% $KMnO_4$) method (Subbiah and Asija, 1956) [16], Available phosphorus (Bray's P) was determined by extracting the acid soil P in dilute acid fluoride (Bray and Kurtz, 1945) [5] phosphorus in the extract was determined colorimetrically at 660 nm as described by Black (1965) [4]. Potassium was determined by Systronics Flame Photometer-128 using neutral-normal-ammonium acetate (NH_4OAc, pH 7.0) as per procedure given by Jackson (1973) [8]. The available Zn in the soil was determined by Atomic Absorption Spectrophotometer as described by Lindsay and Norvell (1978) [9]. Hot water extractable boron method of Berger and Troug (1939) [3] using Azomethine-H reagent. The data obtained were subjected to statistical analysis by following the procedure pertinent to Randomized Block Design as given by Panse and Sukhatme (1967) [11].

Results and Discussion

Yield of sapota

The fruit yield of sapota was significantly influenced by the effect of split application of NPK either sole or with Zn + B (Table 1). Application of RDF alone in two splits (T_2) and three splits (T_4) recorded an increase in fruit yield kg per tree as well as t ha^{-1}. However, the significantly highest fruit yield (46.02 kg/tree and 2.95 t ha^{-1}) was obtained in treatment T_5, where 3 kg NPK each in three splits in June, September and January with $ZnSO_4$ @ 50 g + Borax @ 25 g in June was applied, which was significantly superior over rest of the treatments and followed by the treatment T_4, T_3 and T_2. However, the lowest value of fruit yield was reported in the treatment T_1 (*i.e.*, absolute control). Possible explanation for increase in yield with Zn and B application could be attributed to the fact that Zn is an essential element required by plants for different metabolic process and play vital part in enzyme activation and biosynthesis of specific growth hormones (Noor and Tariq, 2019) [10]. Similarly, B is also involved in metabolism and translocation of carbohydrate, hormonal activities and pollen tube elongation. It also enhances flower initiation, fruit production, N absorption, growth of plants and indirectly influences fruit set (Simmons, 1998) [14].

Table 1: The effect of split application of NPK along with basal dose of Zn and B on yield of sapota

Treat Code	Treatment	Yield kg per tree	Yield (t/ha)
T_1	Absolute control	20.63	1.32
T_2	3 kg NPK in two splits	33.44	2.14
T_3	3 kg NPK in two + Zn & B	36.33	2.33
T_4	3 kg NPK in three splits	38.45	2.46
T_5	3 kg NPK in three splits + Zn & B	46.02	2.95
	S.E.	1.57	0.10
	C.D. at 5%	4.84	0.31

Physico-chemical properties of soil

Application of first split dose of NPK with vermicompost @ 50 kg tree^{-1} with or without Zn + B in the month of June at vegetative flush stage exhibited significant effect on physico-chemical properties and nutrient status of soil at flowering stage and at harvest (Table 2, 3 and 4).

The split application of NPK with and without Zn + B showed significant increase in pH, electrical conductivity and organic carbon content in the soil. Significantly highest pH (5.46 at flowering stage and 5.61 at harvest), EC (0.27 dS m^{-1} at flowering stage and 0.24 dS m^{-1} at harvest) and organic carbon (44.90 g kg^{-1} at flowering stage and 38.20 g kg^{-1} at harvest) were noted in treatment T_5 with the application of 3 kg NPK each in three splits in June, September and January with $ZnSO_4$ + Borax in June, which was found to be at par with the treatments T_2, T_3 and T_4 during both observational stages (with the exception of EC at harvest) (Table 2). The treatment absolute control (T_1) recorded the lowest values of pH, electrical conductivity and organic carbon.

Soil pH increased from vegetative flush stage to harvest stage irrespective of the treatments, which may be due to increased microbial growth and activity during the growth period of the crop as there was increase in organic matter due to accumulation of leaf litter fall during the growth period. The increase in EC with the application of NPK at flowering stage might be due to possible buildup of the soluble nutrients drawn from manure or mineralization, while decrease in EC at harvest may, probably, be due to partial washing away of the salts from the surface soils, besides uptake of the salts from the soil by the plant. The increased organic carbon at flowering stage may probably be due to the soil enrichment in organic carbon content due to several factors such as addition of litter fall, find root biomass recycled and root exudates and its reduced oxidation of organic matter. The establishment of plantations comprising invasive plants reduces tree and shrub layers by exposing the leaf litter layer in this habitat to high temperatures, which accelerated the breakdown of leaf litters and faster the decomposition rates and thus contribute to a decrease in OM content (Singwane and Malinga, 2012) [15].

Application of NPK in two or three splits with or without Zn + B noted the significant increase in available nitrogen, available phosphorus, available potassium content in the soil over the absolute control due to the direct addition of the nutrient through fertilizer to the available pool of the soil. Significantly highest available nitrogen (377.21 kg ha^{-1} at flowering stage and 397.84 kg ha^{-1} at harvest), available phosphorus (7.99 kg ha^{-1} at flowering stage and 7.74 kg ha^{-1} at harvest) and available potassium (872.32 kg ha^{-1} at flowering stage and 887.32 kg ha^{-1} at harvest) were noted with the application of 3 kg NPK each in three splits in June, September and January with $ZnSO_4$ + Borax in June (T_5), which were found to be at par with the treatments T_2, T_3 and T_4 at flowering stage and at harvest in case of above available nutrients (Table 3). No application of fertilizers and vermicompost (*i.e.,* absolute control) recorded the lowest nutrient content in the soil.

The increase in available N status of the soil up to harvest stage with combined use of fertilizers and organic manures may be explained in terms of their residual effect and build up in organic N fractions of the soil due to biochemical degradation and mineralization. Further, organic matter mineralization provides a continuous, although limited, supply of plant available P at flowering (Tisdale *et al*. 1995) [17]. The decline in available phosphorus at harvest may be due to the uptake of P_2O_5 by plants which usually takes place intensively after flowering (Barbatzkii, 1959) [2]. The increase in phosphorous and potassium availability might be also due to synergistic effect of N (Shrivastava, 2002) [13].

The lowest values of DTPA Extractable Zn and available boron content in soil were reported in the treatment T_1 (*i.e.,* absolute control), where fertilizers and organic matter was not applied (Table 4). Further, application of RDF alone in two splits (T_2) and three splits (T_4) recorded increase in DTPA Extractable Zn and available boron. This might be due to efficient utilization of micronutrients in the presence of all other essential elements (Guvvali and Shirol, 2017) [7]. However, the maximum DTPA Extractable Zn and available boron were recorded in treatments T_3 and T_5, where zinc and boron were applied though zinc sulphate and borax. Increase in available boron with borax application might be attributed to the direct addition of boron through fertilizer to the available pool of the soil. Significantly highest DTPA Extractable Zn (2.09 mg kg^{-1} at flowering stage and 1.82 mg kg^{-1} at harvest stage) and available boron (0.47 mg kg^{-1} at flowering stage and 0.38 mg kg^{-1} at harvest stage) were recorded with three split applications of NPK with Zn + B (treatment T_5), which was found to be at par with T_2, T_3 and T_4 in case of DTPA Extractable Zn and with T_3 in case of available boron at flowering stage, while at harvest stage with T_3 in case of DTPA Extractable Zn and T_2, T_3 and T_4 in case of available boron.

Table 2: The effect of split application of NPK along with basal dose of Zn and B on physico-chemical properties of soil

Treatments	pH			EC (dS m^{-1})			OC g kg^{-1}		
	At vegetative flush stage	At flowering stage	At harvest	At vegetative flush stage	At flowering stage	At harvest	At vegetative flush stage	At flowering stage	At harvest
T_1 Absolute control	5.07	5.18	5.31	0.18	0.16	0.16	31.45	35.38	29.85
T_2 3 kg NPK in two splits	5.11	5.23	5.37	0.21	0.24	0.17	32.73	41.15	36.35
T_3 3 kg NPK in two splits + Zn & B	5.12	5.40	5.46	0.22	0.25	0.21	34.03	42.50	37.05
T_4 3 kg NPK in three splits	5.14	5.44	5.58	0.21	0.25	0.22	34.48	44.55	38.15
T_5 3 kg NPK in three splits + Zn & B	5.19	5.46	5.61	0.22	0.27	0.24	34.40	44.90	38.20
S.E.	0.08	0.08	0.08	0.02	0.02	0.02	1.31	2.45	2.01
C.D. at 5%	N.S.	0.23	0.25	N.S.	0.059	0.057	N.S.	7.55	6.18

Table 3: The effect of split application of NPK along with basal dose of Zn and B on physico-chemical properties of soil

Treatments	Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})		
	At vegetative flush stage	At flowering stage	At harvest	At vegetative flush stage	At flowering stage	At harvest	At vegetative flush stage	At flowering stage	At harvest
T_1 Absolute control	282.01	275.76	280.76	5.62	5.74	5.49	590.19	608.11	598.11
T_2 3 kg NPK in two splits	293.99	333.35	359.89	5.75	7.33	7.15	582.51	809.51	837.01
T_3 3 kg NPK in two splits + Zn & B	309.46	352.83	362.94	5.97	7.47	7.22	587.83	829.99	849.99
T_4 3 kg NPK in three splits	290.86	367.18	386.10	5.93	7.75	7.50	602.48	840.13	855.13
T_5 3 kg NPK in three splits + Zn & B	301.32	377.21	397.84	6.06	7.99	7.74	600.22	872.32	887.32
S.E.	8.71	16.37	22.99	0.52	0.38	0.28	38.15	50.58	37.00
C.D. at 5%	N.S.	50.43	70.84	N.S.	1.18	0.86	N.S.	155.85	113.99

Table 4: The effect of split application of NPK along with basal dose of Zn and B on physico-chemical properties of soil

Treatments	DTPA extractable Zn (mg kg^{-1})			Available B (mg kg^{-1})		
	At vegetative flush stage	At flowering stage	At harvest	At vegetative flush stage	At flowering stage	At harvest
T_1 Absolute control	1.12	1.17	1.20	0.20	0.22	0.20
T_2 3 kg NPK in two splits	1.13	1.58	1.28	0.25	0.32	0.27
T_3 3 kg NPK in two splits + Zn & B	1.17	2.07	1.74	0.23	0.45	0.37
T_4 3 kg NPK in three splits	1.13	1.63	1.30	0.24	0.33	0.28
T_5 3 kg NPK in three splits + Zn & B	1.14	2.09	1.82	0.22	0.47	0.38
S.E.	0.08	0.19	0.16	0.04	0.03	0.05
C.D. at 5%	N.S.	0.58	0.50	N.S.	0.10	0.14

Conclusion
Considering the yield of sapota, physico-chemical properties of soil and soil available nutrient status, application of 3 kg NPK each tree $^{-1}$ in three equal splits in June, September and January with 50 kg Vermicompost and 50 g $ZnSO_4$ + 25 g Borax tree $^{-1}$ in June was found to be superior and beneficial in lateritic soils of Konkan from the view point of getting higher fruit yields of sapota variety Kalipatti and maintaining the soil fertility.

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