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Assessing nutrient uptake pattern with respect to dry matter accumulation in Ney Poovan (AB) banana at critical growth stages

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ABSTRACT

A field experiment was conducted to assess the nutrient uptake pattern and partitioning of nutrients in Ney Poovan banana (AB) at critical growth stages like 10-leaf stage, 20-leaf stage, shooting stage and harvesting stage. From 10-leaf stage to harvesting, the per cent dry matter (DM) accumulation decreased from 42 to 16 in underground segment and increased from 58 to 84 in above ground segment. The sample was partitioned into root, corm, pseudostem, leaf lamina, petiole, peduncle, bunch and male bud, processed and analysed for macro and micronutrients at different critical growth stages. The nutrient accumulation pattern, with respect to dry matter production was worked out. To produce 37.5 t banana ha^{-1}, about 444 kg N, 69 kg P, 933 kg K, 2.4 kg Cu, 7.3 kg Mn, 3.4 kg Fe and 5.9 kg Zn were taken up by Ney Poovan banana. About 10 to 52% removal occurred through bunch harvest from the total nutrient uptake from the soil and remaining nutrients accumulated in the residual tissues were available for *in situ* recycling. The data provided opportunity for proper fertiliser scheduling to achieve optimum yield with higher nutrient use efficiency and nutrient budgeting in banana ecosystem was also done.

Key words: *Musa paradisiaca*, macro and micronutrients, nutrient use efficiency, nutrient budgeting

INTRODUCTION

Banana provides food, and nutritive and social security to millions of people across the globe. Banana is the second most important fruit crop in India next to mango. It accounts for 37% of total fruit production with a total estimated annual production of 29.1 million tonnes from 0.85 million ha. Bananas use considerable amounts of mineral nutrients for growth and fruit production (Lahav, 6). The fertiliser recommendations are based on yield data collected from previous studies. Mostly Indian banana farmers adopt blanket fertiliser recommendations of their state horticultural universities and departments. Banana being long duration crop (10-14 months), it requires different nutrients at different levels at different growth stages due to their significant variations in these nutrient accumulations patterns in different organs. The blanket fertiliser recommendations with split application of nutrients, adopted in different banana growing areas of India are not matching exactly with the nutrient uptake and accumulation pattern, as observed by Sitthaphanit *et al*. (10). Because of this mismatching, the 'use efficiency' of nutrients is not optimised properly. The information on dry matter accumulation, nutrient uptake pattern and nutrient mobility characteristics provide an opportunity to optimize fertiliser application and helps us to avoid nutrient losses by different means (Moustakas and Ntzanis, 7). Lack of information on nutrient uptake and accumulation pattern in banana at different growth stages, leads to indiscriminate application of fertilisers (Jeyabaskaran *et al*., 5). As banana produces comparatively smaller edible portion (fruits) with larger bio mass production, *in situ* nutrient recycling of residues after bunch harvesting is considered to play major role in fertiliser management in banana based cropping system. Hence, in the present study, an attempt was made to assess the nutrient uptake and accumulation pattern with respect to dry matter accumulation in different organs at different growth stages of Ney Poovan banana plant and for nutrient budgeting in banana based cropping system.

MATERIALS AND METHODS

The Field experiment was conducted with Ney Poovan (AB) banana during 2013-2014 in silty clay loam soil (*Typic Ustropept*, mixed, hyperthermic) of research farm of ICAR-NRC for Banana, Tiruchirapalli, Tamil Nadu. The chemical properties of the experimental site was pH – 8.7, EC – 0.2 dSm^{-1}, Organic Carbon – 0.23%, $CaCO_3$-5.2%, CEC – 11.5 cmol kg^{-1}, N – 230 kg ha^{-1}, P_2O_5 – 8.5 kg ha^{-1}, K_2O – 150 kg ha^{-1}. Ney Poovan suckers were planted with the spacing of 2m × 2m with basal dose of (2 kg FYM + 1 kg vermicompost) plant^{-1}, after proper sucker treatments. Full of phosphorus (P), 30 g plant^{-1} at planting and the Nitrogen (N), 200 g

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plant^{-1} and Potassium (K), 400 g plant^{-1} were given as soil application in three equal splits at 3 months after planting (MAP), 5 MAP and 7 MAP. Ten plants each at 10-leaf stage, 20-leaf stage, shooting and harvesting were uprooted carefully, segmented into root, corm, pseudostem, petiole, leaf lamina, peduncle, bunch and male bud and every segmental tissue samples were collected for analyzing nutrient contents. These segments were dried and used for estimating dry matter (DM) accumulation and nutrient uptake. The segmental tissue samples were dried to a constant weight at 60^{o}C, processed and analysed for macronutrients (N, P and K), using standard procedures as described by Jackson (4) and micronutrients (Cu, Mn, Zn and Fe) using Atomic Absorption Spectrometer (Varian SpectrAA200 model). Nutrient accumulations were worked out based on the tissue nutrient concentrations with respect to DM accumulation in different segments at 10-leaf stage, 20-leaf stage, shooting and harvesting stages. Harvesting index was calculated as the content of nutrients in the bunch along with peduncle relative to the total nutrient uptake.

Using Microsoft Excel software, cubic polynomial curves were generated for DM accumulation and nutrient uptake with respect to 10 leaf stage, 20 leaf stage, shooting and harvesting for assessing the DM and nutrient accumulation pattern in different segments like root, corm, pseudostem, petiole, leaf lamina, peduncle, bunch and male bud. These cubic polynomial curves were used for predicting nutrient uptake and accumulations with respect to dry matter production, in different segments of Ney Poovan banana plant during these growth stages. The adjusted R^2 value between the predicted and observed values is high and ensures statistical integrity of the curve.

RESULTS AND DISCUSSION

Till 10-leaf stage, only 1.7% of total DM accumulation took place and it gradually increased up to 59.4% till the shooting stage. The rest of 40.6% DM accumulation took place very rapidly during shooting to harvesting stage, which coincided with the bunch formation and development (Table 1). The DM accumulation in root increased from 0.1 to 0.7 t ha^{-1} from 10-leaf stage to harvesting with an attainment of more than 85.7% total DM accumulation (0.6 t ha^{-1}) at shooting stage. The rate of root DM accumulation during 10-leaf stage to 20-leaf stage was more than that during between other growth stages. Similar trend of root DM accumulation was observed by Sylvio *et al*. (12) in plantain cv. Dominico Harton. Thus, the rapid emergence and proliferation of root system occurred during 10-leaf stage to 20-leaf stage in Ney Poovan banana to facilitate optimum nutrient uptakes from soil during rest of its growth period (Table 1). The same trend was observed between 10-leaf stage and harvesting with increasing corm DM accumulation from 0.2 to 4.2 t ha^{-1} with slightly diminishing rate till shooting, which may be due to simultaneous redistribution of DM in the plant system, as observed by Twyford and Walmsley (16).

The pseudostem DM accumulation increased from 0.1 t ha^{-1} at 10-leaf stage to 8.3 t ha^{-1} at harvesting, with more or less uniform rate. The DM accumulations in leaf petiole increased from 0.05 to 1.0 t ha^{-1} and in leaf lamina from 0.2 to 4.3 t ha^{-1} with increasing duration of Ney Poovan. The leaf petiole and leaf lamina DM accumulation attained 100% of its total DM accumulation at shooting with steep increments from 10-leaf stage to shooting. A slight and non-signficant drop in DM accumulation in petiole and leaf lamina was observed during shooting to harvesting. This is attributed to drying and shredding of older leaves (Harper, 3 and Rodriguez *et al*., 8).

The total DM accumulation increased from 0.5 t ha^{-1} at 10-leaf stage to 30.8 t ha^{-1} at harvesting. The rates of increase in total DM accumulations during 10-leaf stage to 20-leaf stage and during shooting to harvesting were faster than that during 20-leaf stage to shooting. This lagging of rapidity in total DM accumulations between 20-leaf stage and shooting is attributed to more redistribution of DM within the plant system than accumulation of fresh DM. The sudden increase in total DM accumulation after shooting was attributed to formation and development of peduncle and bunch, which acted as sink of DM. It is interesting to note that about 59.4% of total DM accumulation took place till shooting and rest of 40.6% of total DM accumulation took place after shooting and harvesting index was worked out to be 39.3% (Table 1). This clearly indicated that after shooting, photosynthesis, carbon sequestration or accumulation, carbohydrate metabolism etc. play more crucial roles than in any other periods of plant growth, for optimum yield. These observations are in corroboration with that of Twyford and Walmsley (16), Bender *et al*. (1) and Thangasamy (13).

The total N uptake increased from 34.85 kg ha^{-1} at 10-leaf stage to 444.3 kg ha^{-1} at harvesting (Table 1). The N uptake rate was more rapid during 20-leaf stage to shooting than that before 20-leaf stage and after shooting stage. As most of the leaf production took place till shooting, more than 64% of total N uptake was over till shooting and the rest of 36% total N uptake took place after shooting. This trend of N uptake emphasises more than 75% N fertilisation requirements in fertilizer scheduling

Table 1. Accumulations of dry matter and nutrients in different segments at growth stages in Ney Poovan banana.

Growth Stages	Root	Corm	Pseudo-stem	Petiole	Leaf lamina	Peduncle	Bunch	Male Bud	Total	Harvest Index (%)
					DM accumulation (t ha^{-1})					
10 leaf	0.1	0.2	0.1	0.0	0.2	-	-	-	0.5	
20 leaf	0.4	2.1	2.9	0.6	2.4	-	-	-	8.5	
shooting	0.6	4.0	6.9	1.2	5.1	-	-	0.5	18.3	
harvest	0.7	4.2	8.3	1.0	4.3	2.1	10.0	0.3	30.8	39.3
					Nitrogen (kg ha^{-1})					
10 leaf	0.75	2.70	6.28	0.55	24.58	-	-	-	34.85	
20 leaf	2.18	9.60	21.68	1.43	46.38	-	-	-	81.25	
shooting	4.20	22.50	114.53	13.18	123.18	-	-	8.35	285.93	
harvest	4.43	22.65	159.73	15.75	128.23	47.95	63.65	1.93	444.30	25.1
					Phosphorus (kg ha^{-1})					
10 leaf	0.40	1.93	2.73	0.70	3.45	-	-	-	9.20	
20 leaf	0.93	4.73	8.75	1.68	7.78	-	-	-	23.85	
shooting	3.48	10.58	24.25	3.25	12.40	-	-	1.25	55.20	
harvest	3.60	5.08	22.28	2.93	10.95	4.50	19.05	0.48	68.85	34.2
					Potassium (kg ha^{-1})					
10 leaf	12.05	34.28	75.48	13.38	30.23	-	-	-	165.40	
20 leaf	25.13	80.28	165.63	28.88	64.13	-	-	-	364.03	
shooting	27.15	90.70	330.75	48.85	112.20	-	-	15.15	624.80	
harvest	9.60	61.95	259.53	19.88	92.55	196.40	288.40	4.15	932.45	52.0
					Copper (kg ha^{-1})					
10 leaf	0.03	0.05	0.13	0.01	0.05	-	-	-	0.25	
20 leaf	0.05	0.18	0.28	0.05	0.15	-	-	-	0.70	
shooting	0.05	0.28	0.60	0.08	0.30	-	-	0.03	1.33	
harvest	0.08	0.43	0.98	0.10	0.35	0.10	0.35	0.00	2.38	18.9
					Manganese (kg ha^{-1})					
10 leaf	0.03	0.25	0.28	0.05	0.23	-	-	-	0.83	
20 leaf	0.10	0.53	0.73	0.15	0.60	-	-	-	2.10	
shooting	0.15	0.95	1.63	0.28	1.18	-	-	0.05	4.23	
harvest	0.30	1.98	2.53	0.48	1.30	0.28	0.45	0.03	7.33	9.9
					Zinc (kg ha^{-1})					
10 leaf	0.00	0.03	0.05	0.01	0.05	-	-	-	0.13	
20 leaf	0.03	0.05	0.05	0.03	0.05	-	-	-	0.20	
shooting	0.03	0.25	0.88	0.03	0.10	-	-	0.00	1.28	
harvest	0.03	0.25	0.98	0.03	0.48	0.18	1.43	0.00	3.35	48
					Iron (kg ha^{-1})					
10 leaf	0.05	0.10	0.33	0.05	0.35	-	-	-	0.88	
20 leaf	0.13	0.48	0.75	0.15	0.80	-	-	-	2.30	
shooting	0.15	0.80	1.63	0.33	1.65	-	-	0.10	4.65	
harvest	0.05	0.68	2.60	0.03	1.08	0.48	0.95	0.03	5.88	24.3

before shooting in Ney Poovan banana cultivation. Leaf lamina along with petiole had the highest content of nitrogen and the pseudostem along with corm was the next repository, till shooting. These are similar to the observations of Twyford and Walmsley (15). It was inferred that underground DM accumulated only 6% total N uptake and the aboveground DM accumulated remaining 94% total N uptake, at harvesting. It was worked out that about 112 kg of N was removed from one hectare soil through harvest of bunch along with peduncle and it accounted for 25% of total N uptake, in Ney Poovan banana. Hence, the remaining 332 kg of N available in the plant residues of one hectare could be used for *in situ* recycling.

The total P uptake reached a peak of 68.85 kg ha^{-1} at harvest from 9.20 kg ha^{-1} at 10-leaf stage. More than 80% achievement of total P uptake was observed at shooting. Similar to N uptake pattern, the P uptake rate was more rapid during 10-leaf stage to shooting. About 46% of total P uptake took place during 20-leaf stage to shooting and it emphasises more P fertilisation requirements in fertilizer scheduling during this growth period, which coincides with higher rate of root proliferation. Unlike N, the P contents in segments like root, corm, pseudostem, petiole, leaf lamina increased significantly till shooting and decreased significantly after shooting. This decreasing of P contents in these segments is attributed to redistribution of P in the newly formed and developing segments like peduncle and bunch during shooting to harvesting, as observed by Twyford and Walmsley (15). About 13% of total P uptake was accumulated in the underground DM and remaining 87% accumulated in the aboveground DM. It was worked out that 23.6 kg of P was removed from one hectare soil through harvest of bunch along with peduncle, which accounted for 34% of total P uptake in Ney Poovan banana. The remaining 45.3 kg of P available in the residues of one hectare could be recycled *in situ*.

The K uptake was found to be the highest among the nutrients taken up by banana (Sathiyamoorthy and Jeyabaskaran, 9). The total K uptake and rate of uptake increased steadily from 10-leaf stage to harvesting. The K uptake increased from 165.4 kg ha^{-1} at 10-leaf stage to 932.45 kg ha^{-1} at harvesting. The per cent total K uptakes observed till 10-leaf stage, during 10-leaf stage to 20-leaf stage, during 20-leaf stage to shooting and during shooting to harvesting were worked out to be 18, 21, 28 and 33, respectively and this emphasises gradual and steady increase of K fertilisation requirements in fertilizer scheduling with increasing growth period in Ney Poovan banana cultivation. Though there was rapid increase in K contents in segments like root, corm, pseudostem, petiole, leaf lamina till shooting, a drastic reduction of K contents in these segments was registered during formation and development of peduncle and bunch due to redistribution of K in these regions, as well as increased K uptake (Table 1). These observations are in acceptance with Twyford and Walmsley (16). At harvesting stage, the underground DM accumulated only 7% total K uptake where as the aboveground DM accumulated 93%. During harvesting of bunches along with peduncle, about 485 kg of K was removed from one hectare, which worked out to be 52% of total K uptake and remaining 48% (448 kg K) was available for *in situ* recycling. Similar observations were also made by Delvaux *et al*. (2). These observations caution about K-mining that happens in banana growing soil and emphasises suitable and immediate K replenishment in soil for sustainable production and productivity of quality bananas in Indian conditions as observed by Srinivasarao *et al*. (11).

The Cu uptake was found to be the least among the nutrients taken up by Ney Poovan banana. The Cu uptake and its rate increased gradually and steadily throughout the period from 10-leaf stage to harvesting, with total Cu uptake from 0.25 to 2.38 kg ha^{-1}, respectively. At harvesting stage, the per cent accumulations of Cu in DMs of underground and aboveground were 21 and 79, respectively, which accounted for 0.5 and 1.9 kg Cu in one hectare, respectively (Table 1). Only 0.45 kg of Cu was worked out to be removed from one hectare soil through harvesting of bunch along with peduncle and 1.9 kg was available for *in situ* recycling. The total Mn uptake at harvesting was 7.33 kg ha^{-1}, which was attained from 0.83 kg ha^{-1} at 10-leaf stage with gradual and steady rate and this is in corroboration with the findings of Twyford and Walmsley (14). In one hectare, at harvesting stage, the DM of underground accumulated 2.3 kg and that of aboveground 4.5 kg Mn, which accounted for 31% and 69% of total Mn uptake, respectively. About 0.73 kg Mn was worked out to be removed from one hectare soil during harvesting of bunches along with peduncle and about 6.6 kg of Mn was available for *in situ* recycling. The total Zn uptake increased from 0.13 kg ha^{-1} at 10-leaf stage to 3.35 kg ha^{-1} at harvesting, with sudden rapidity during shooting to harvesting. About 65% of the total Zn accumulation took place during shooting to harvesting stage, indicating the importance of Zn fertilisation in Ney poovan banana cultivation during this period for optimum yield. There was no variation in Zn accumulation in DM of underground during shooting to harvesting, while there was rapid increase in Zn accumulation in DM of aboveground.

At harvesting, the per cent Zn partitioning in DM of underground and that of aboveground was 8 and 92, respectively, which accounted to 0.28 and 3.07 kg ha^{-1}. Harvesting of bunches along with peduncle in one hectare removed 1.61 kg of Zn and 1.74 kg Zn was available in the residues for *in situ* recycling. Unlike other micronutrients, though the total Fe uptake increased from 0.88 kg ha^{-1} at 10-leaf stage to 5.88 kg ha^{-1} at harvesting, the rate of Fe uptake decreased from shooting to harvesting, which emphasised importance of Fe fertilisation in fertilizer scheduling during the period before shooting. During shooting to harvesting, the Fe accumulation in different segments decreased in segments like root, corm, petiole, leaf lamina and male bud. At harvesting stage, the Fe accumulation in DM of underground was 0.73 kg ha^{-1} and that of aboveground was 5.15 kg ha^{-1}. Harvesting of bunches with peduncle in one hectare removed Fe at the rate of 1.43 kg ha^{-1} and 4.45 kg Fe ha^{-1} was available in the residues to be recycled *in situ*.

In conclusion, these results clearly indicated that as the nutrient uptake and accumulation pattern with respect to DM accumulation varies with nutrients and plant growth stages, equal splitting of fertiliser application in nutrient management, as per blanket recommendations could not match these patterns and lead to very low use efficiency of nutrients. Thus, it is understood from this study that the N and P fertilisation in soil for banana should follow the least quantity during early vegetative stage (10-leaf stage to 20-leaf stage) and the highest quantity during late vegetative stage (20 leaf stage to shooting), followed by moderate quantity during shooting to harvesting while, the K fertilisation in soil should follow a pattern of the least during early vegetative stage to the highest during shooting to harvesting, with rapid increasing uptake rate. Among the micronutrients, the uptake and accumulation pattern of copper and manganese followed the same trend of the lowest quantity at early vegetative stage and the highest during shooting to harvesting, with rapid increase in uptake rate, similar to that of potassium. But, the zinc and iron uptake rate was more rapid during late vegetative stage than early vegetative stage and shooting to harvesting stage.

In the present study, the nutrient budgeting in Ney Poovan cultivation revealed that with the production of 37.5 t Ney Poovan banana per hectare, about 112kg N, 24kg P, 485kg K, 0.5kg Cu, 0.7kg Mn, 1.6kg Zn and 1.4kg Fe had been removed through harvest of bunch along with peduncle and about 332kg N, 45kg P, 447kg K, 1.9kg Cu, 6.6kg Mn, 1.8kg Zn and 4.5kg Fe had been immobilised in the residual tissues, which could be mobilised and utilised for next crop through *in situ* recycling. These data also suggest that *in situ* dehanding of bunch instead of harvesting whole bunch along with peduncle may facilitate to increase quantity of available recyclable nutrients considerably in the banana ecosystem through reincorporation of peduncle and rachis also in the soil. These data generated from this experiment will provide a clear cut idea for optimum fertiliser scheduling in banana based cropping system.

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