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Assessment of dry matter accumulation and nutrient uptake pattern of garlic

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ABSRACT

Field experiment was conducted to assess dry matter accumulation and nutrient uptake pattern of garlic. Plant samples were collected at 15 day interval from planting to harvest. The samples were partitioned, processed and analysed for macro and micronutrients. Results showed that total nutrients required to produce 6.7 t garlic bulbs/ha was 56.3 kg N, 13.5 kg P, 65.8 kg K, 30.6 kg S, 110.3 g Zn, 116.9 g Mn, 724.9 g Fe, and 26.2 g Cu. Garlic plants accumulated 84.7 and 84.6% of total nitrogen (N) and potassium (K) from planting to 75 days after planting (DAP). The peak N and K uptake coincided with the active vegetative growth stage. Whereas, the total phosphorus (P), sulphur (S), zinc (Zn), iron (Fe), manganese (Mn) and copper (Cu) uptake accounted for 59.5-66.7% of total uptake from planting to 75 DAP accounted. The peak uptake of these nutrients coincided with bulb initiation and development stages. Subsequently, an effective nutrient schedule could be developed for adoption by farmers.

Key words: Garlic growth stages, macronutrient, micronutrient, nutrient uptake.

INTRODUCTION

Garlic (*Allium sativum*) is the second important bulbous crops grown in India. On the global scale, India ranks second next to China in the world's garlic production and contributes 14% of the world area and 5% of production. Garlic productivity has increased from 3.90 t/ha in 1990-91 to 5.44 t/ha in 2013-14 (NHRDF, 9). The national garlic productivity has increased by about 40% during a period of 24 years from 1990-91 through 2013-14. The increased garlic productivity could be due to adoption of improved cultivars, refinements of agronomic practices such as adjusting planting dates, plant spacing, plant protection measures and greater nutrient uptake and extended nutrient uptake pattern. However, the fertilizer recommendations are based on yield and nutrient uptake data collected from previous studies and older cultivars.

As per the current fertilizer management practices, farmers apply 30-50% of required nitrogen (N) and 100% phosphorus (P), potassium (K) and sulphur (S) at the time planting as a basal application and the remaining N in splits at 30 and 45 days after planting (DAP). As the plants require about 20% of total nutrients during the first 4 weeks of plant growth, basal application of fertilizer nutrients do not match with peak crop demand (Sitthaphanit *et al.*, 11). Being a shallow rooted crop, its root system is restricted to surface 0-15 cm only during the first 30 days of crop growth. While, the unused fertilizer nutrients applied as a basal dose may be leached to the sub-surface along with irrigation water and become unavailable to the plants. The information on dry matter (DM) accumulation, nutrient uptake pattern and nutrient mobility characteristics provides an opportunity to optimize fertilizer application and helps us to avoid nutrient losses by different means (Moustakas and Ntzanis, 8; Meng *et al.*, 7). Patterns for mineral assimilation are typically nutrient specific and vary in the timing, rate and duration of uptake as well as the tissues to which nutrients are partitioned (Bender *et al.*, 3). Therefore, there is a critical need for re-evaluation of dry matter accumulation and nutrient uptake pattern in garlic using improved cultivars and management practices. The information related to DM accumulation and nutrient uptake pattern is lacking for the garlic crop. Hence, the present study was undertaken to quantify DM accumulation and nutrient uptake pattern in garlic cv. Bhima Omkar.

MATERIALS AND METHODS

Field experiment was conducted to assess the dry matter (DM) accumulation and nutrient uptake pattern of garlic cv. Bhima Omkar during 2011-12 in clay loam soil (*Typic Haplustept*) at ICAR-DOGR, Rajgurunagar, Pune. The garlic was planted on November 2, 2011 with 15 × 10 cm plant spacing . The recommended fertilizers (100:50:50:50 kg NPKS/ha) and farmyard manure (FYM) (20 t/ha) were applied to raise the crop. Full of phosphorus (P), potassium (K), sulphur (S), FYM and 34% nitrogen (N) were applied during planting as a basal dose. Remaining two third of N fertilizer was applied at 30 and 45 days after planting (DAP). Ten plants per

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plot was collected at 15 day interval from 30 to 120 DAP for assessing dry weight and nutrient analysis. Plant samples were partitioned into leaves and bulbs after washing. Later, samples were dried to a constant weight at 60°C and were used to determine the leaf and bulb dry weights. Dried samples were processed and analyzed for macro (N, P, K and S) and micronutrients (Fe, Mn, Zn and Cu) using standard procedures as described by Jackson (5). Nutrient uptake was calculated by multiplying plant nutrient concentration with the dry weight. Harvest index was calculated as the content of nutrients in the bulbs relative to the total aboveground nutrient uptake.

Cubic polynomial equation was used for predicting dry matter accumulation and nutrient uptake pattern. This equation illustrates the relationship between production and time. Hence, the growth rate, *i.e.* increase in production per unit time was calculated from the first derivative of the above equation. DM accumulation and nutrient uptake data recorded during the growth stages were fitted to the cubic polynomial equation using statistical analysis software (SAS) JMP version 10.2 after testing the data for fitness. The adjusted R^2 value between predicted and observed values is high and ensures statistical integrity of the curve. DM accumulation and nutrient uptake curves were prepared using the graph builder option in SAS JMP version 10.2.

RESULTS AND DISCUSSION

The results showed that dry matter (DM) accumulation in leaves increased slowly up to 15 days after planting (DAP) (Fig. 1). DM accumulation in leaves during initial 15 days accounted for 4.7% of total accumulation. The gradual accumulation during this period could be due to slow adaptation of the newly germinated plants to their new environment. DM accumulation rate in leaves increased rapidly after 15 days and reached the peak at 50 DAP. Whereas, after 50 days, the accumulation rate decreased and reached a negative value at 105 DAP. This decrease in DM accumulation in leaves was due to drying and shredding of older leaves (Harper, 4; Rodriguez *et al.*, 10). DM accumulation in bulbs progressed steadily after 30 days and reached the peak at harvest with the accumulation rate of 83.8 kg/ha/day. Total DM accumulation in garlic (leaves + bulbs) increased rapidly after 30 days and reached peak at 80 DAP. The accumulation rate decreased after 80 days and showed 37.8 kg/ha/day at 120 DAP. Total DM accumulation up to 75 days accounted for 49.4% of total accumulation. The remaining 50.6% were accumulated between 75 DAP and harvest, whereas, DM accumulation in bulbs during the same period accounted for 70.9%. This increase in DM accumulation in bulbs 75 DAP could be partly due to remobilization and translocation of photosynthates accumulated in leaves to bulbs at maturity stage (Bender *et al*., 3). Similar pattern of DM accumulation was observed in onion bulb crop as well (Sullivan *et al*., 12; Thangasamy, 13).

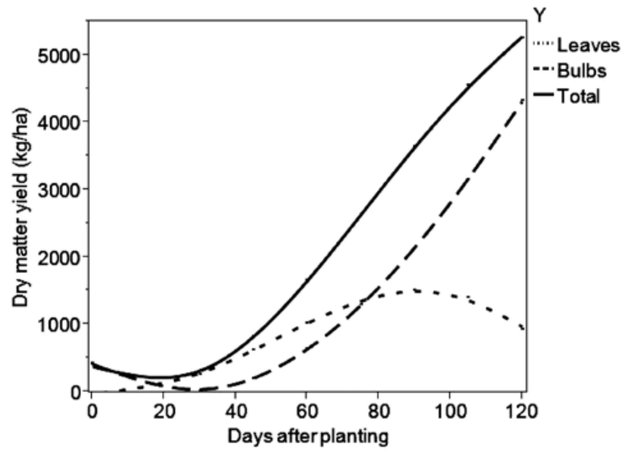

Fig. 1. Dry matter accumulation pattern of garlic crop from planting to harvest.

Total N and K uptake increased slowly up to 15 DAP and rapidly thereafter. Peak N and K uptake rate was observed at 49 and 50 DAP, respectively. Total uptake rate was decreased and showed negative value at 105 DAPS. N and K uptake followed the similar trend of DM accumulation pattern in leaves. Alva *et al*. (1) and Bender *et al*. (3) have reported that DM accumulation in leaves was closely related with N. Total N and K uptake rate showed negative value at 105 DAP, whereas, the uptake rates in bulbs remained positive at 120 DAP. This indicated that the N accumulated in leaves could be remobilized and translocated to bulbs at maturity stages due to their higher mobility in phloem. Similar uptake pattern was observed in maize and soybean by Bender *et al*. (3) and Bender *et al*. (2). The total N and K uptake from planting to 75 DAP accounted 84.7 and 84.6 percent of total uptake. The remaining 15.3 and 15.4% of total N and K were accumulated from 75 days to till harvest. Similar uptake pattern was observed in wheat by Meng *et al*. (7) and in rice by Ye *et al*. (14). Peak N and K uptake coincided with active vegetative growth stage and showed that demand for these nutrients were higher during this stage. Bender *et al*. (3) reported that timing of nutrient acquisition was nutrient specific and associated with key growth stages. Application of these nutrients after 75 days is seldom effective in increasing the nutrient use efficiency and garlic yield. Similar observations were recorded in onion bulb crop (Sullivan *et al*., 12; Thangasamy, 13) and maize (Karlen *et al*., 6; Bender *et al*., 3).

Total phosphorus (P) and sulphur (S) uptake increased slowly up to 20 DAP and rapidly thereafter (Fig. 2 & 3). Total P and S uptake rate attainted peak at 70 and 64 DAP, respectively. Unlike N and K, P and S uptake followed total DM accumulation pattern. The uptake rate in bulbs continued to increase till harvest at 120 DAP, whereas, total P and S uptake rate showed 0.04 and 0.02 kg/ha/day, respectively. This could be due to remobilization of P and S accumulated in leaves to bulbs during maturity stage due to their high mobility in phloem (Bender *et al*., 2). P and S uptake from planting to 75 DAP accounted for 59.5 and 63.7% of total uptake. While, remaining quantity of these nutrients were removed between 75 and 120 DAP. Peak P and S uptake coincide with bulb initiation and bulb development stages. Sullivan *et al.* (12) reported that these nutrients are essential for onion bulb initiation and development in onion.

Micronutrient uptakes increased slowly up to 20 DAP and rapidly after 20 days (Fig. 4 & 5). The peak uptake a rate of Zn, Fe and Cu was observed at 64-65 DAP, while, at 57 DAP, the peak Mn uptake occurred. The total uptake rates of all these nutrients showed negative value at 120 DAP. Micronutrients uptake pattern followed a similar trend as that of total DM accumulation. Unlike N, P, K and S uptake, the micronutrient uptake rate in bulbs and total uptake rate decreased at maturity stages. This indicated that these nutrients are immobile in phloem and could not be translocated from leaves to bulbs. Similar results were previously reported in transgenic maize (Bender

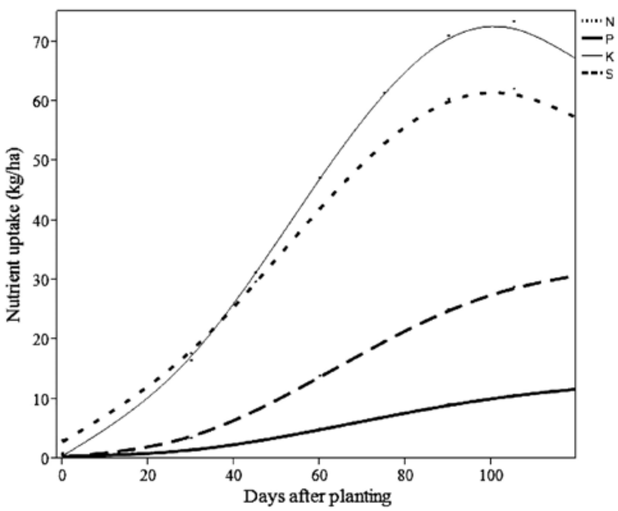

Fig. 2. Major nutrient uptake pattern in garlic.

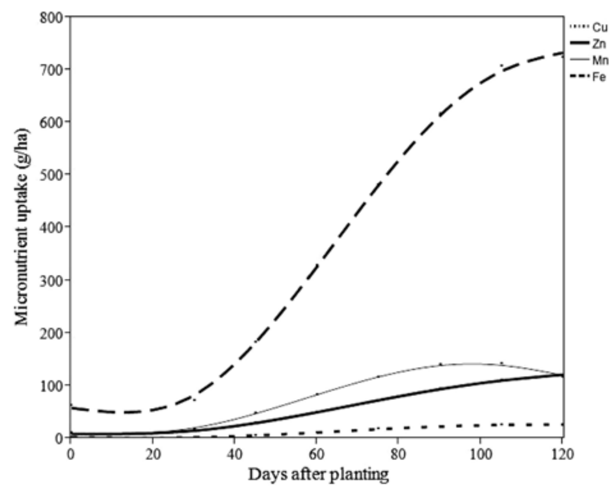

Fig. 4. Micronutrient uptake pattern in garlic.

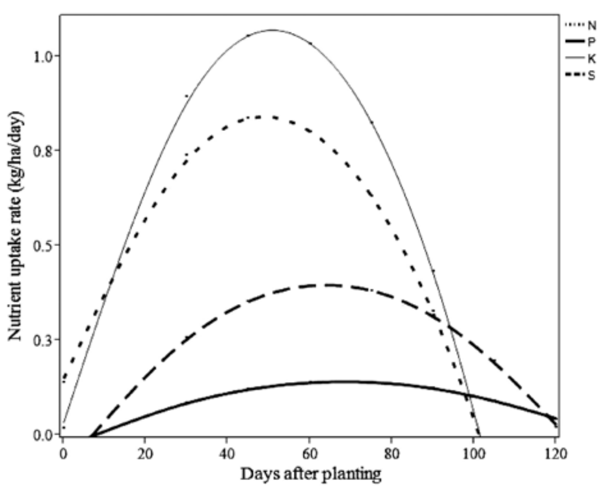

Fig. 3. Major nutrient uptake rate in garlic.

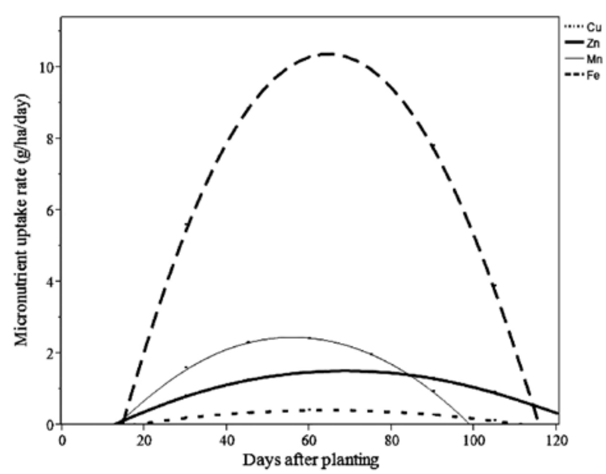

Fig. 5. Micronutrient uptake rate in garlic.

et al., 3) and soybean (Bender *et al.*, 2). Micronutrient uptake pattern showed that season-long supply of these nutrients are required for obtaining higher bulb yield. Like P and S, total Zn, Fe and Cu uptake from planting to 75 DAP accounted for 64.0, 65.7 and 66.7% of total uptake and acquired the remaining quantity after 75 days. The peak uptake rate of these nutrients coincided with bulb initiation and development stages and showed that these elements are essential for bulb initiation and development. Whilst, Mn followed similar trend as that of N and K uptake pattern.

The garlic crop as such accumulated 82.4% of total biomass in bulbs compared to 17.6% in leaves (Table 1). This crop removed 56.3 kg N, 13.5 kg P, 65.8 kg K, 30.6 kg S, 110.3 g Zn, 116.9 g Mn, 724.9 g Fe, and 26.2 g Cu to produce 6.7 t garlic bulbs/ha. Total N, P, K and S uptake in bulbs accounted for 71.5, 84.2, 64.4 and 93.8% of total uptake, respectively. The plants removed 87.0% Fe, 84.9% Cu, 84.0% Zn and 61.1% Mn in bulbs. The nutrients moved to economic part (bulbs) were high compared to leaves. Among different nutrients analysed, more than 80% of nutrients were accumulated in bulbs except for K and Mn. Concentration of K and Mn were higher in leaves compared to bulbs. Similar results were observed in onion bulb crop (Thangasamy, 13) and soybean (Bender *et al.*, 2). The nutrient harvested in bulbs needs to be replaced through fertilizers and manures for sustaining soil health and productivity, whereas, the nutrients accumulated in above ground portion could be recycled through reincorporation of the same.

Our results showed that N and K demand was higher during active vegetative growth stage (15 to 75 days). Comparatively, peak P and S coincided with bulb initiation and development stages. However, farmers apply large quantity of fertilizers (25-50% N and full dose of PKS) at the time of planting. Application of large quantities of fertilizers before planting is likely to move beyond root zone along with irrigation water; while, application during maturity (after 75 days) is seldom effective in increasing nutrient use efficiency and bulb yield. The fertilizer application should coincide with rapid nutrient uptake stages to increase yield and nutrient use efficiency. Due to immobility of micronutrients in phloem, the season-long supply of micronutrients is essential to improve the yield and quality of bulbs. The data generated from this experiment will provide an opportunity to optimize fertilizer scheduling to increase nutrient use efficiency and bulb yield.

Table 1. Nutrient uptake in leaves and bulbs of the garlic and harvest index.

Dry matter/ nutrient	Dry matter/ nutrient uptake			Harvest index (%)
	Leaf	Bulb	Total	
Dry matter yield (kg/ha)	923.0	4329.0	5253.0	82.4
Nitrogen (kg/ha)	16.0	40.2	56.3	71.5
Phosphorus (kg/ha)	2.1	11.4	13.5	84.2
Potassium (kg/ha)	23.4	42.4	65.8	64.4
Sulphur (kg/ha)	1.9	28.7	30.6	93.8
Zinc (g/ha)	17.7	92.7	110.3	84.0
Manganese (g/ha)	45.5	71.3	116.9	61.1
Iron (g/ha)	93.9	631.0	724.9	87.0
Copper (g/ha)	3.9	22.2	26.2	84.9

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