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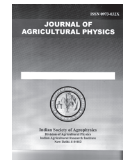

Research Article

Impact of FYM, Phosphorus Sources and Nitrogen Application Stages on Dry Biomass Yield, Nutrient Uptake and Soil Availability under *Rabi* Onion Cultivated in Alluvial Soil

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ABSTRACT

Onion is the most extensively cultivated crop used for multiple purposes, including vegetable, spices and medicine. The present study was conducted to study the impact of FYM, phosphorus sources and nitrogen application stages on dry biomass yield, nutrients uptake and soil availability after *rabi* onion for two consecutive *rabi* seasons (2020-21 and 2021-22) with onion variety 'PRO-7' in sandy loam alluvial soil. Treatment T_4: FYM @ 50 t ha^{-1} + N@100 kg ha^{-1} at 30 and 60 days after transplanting + P_2O_5@ 50 kg ha^{-1} through diammonium phosphate (DAP) produced maximum leaves (9.8 q ha^{-1}) and bulbs (21.09 q ha^{-1}) dry matter, total macro and micro-nutrients content (N:5.77%, P: 1.26%, K: 5.1%, Fe:155.8 mg kg^{-1}, Cu:51.8 mg kg^{-1}, Zn:84.1 mg kg^{-1}, Mn: 63.4 mg kg^{-1}) and uptake (N:100.3 kg h^{-1}, P:20.6 kg h^{-1}, K:80.9 kg h^{-1}, S:12.8 kg h^{-1}, Fe: 238.6 g h^{-1}, Cu:80.2 g h^{-1}, Zn:129.5 g h^{-1}, Mn: 98.7 g h^{-1}) and it was statistically at par with T_3: FYM @ 50 t ha^{-1} + N @100 kg ha^{-1} at 15 and 45 days after transplanting + P_2O_5 @ 50 kg ha^{-1} through DAP. Similarly, T_4 also showed significantly higher soil macro (N: 199.6 kg h^{-1}, P: 57.3 kg h^{-1}, K: 261.5 kg h^{-1}) and micro-nutrients (Fe: 6.50 g h^{-1}, Cu: 0.61g h^{-1}, Zn: 1.09 g h^{-1}, Mn: 5.13 g h^{-1}) after crop harvest. Decrease in dry biomass (12 to 15%), macro-nutrients content (5-25%) and uptake (20-36%), micro-nutrients content (6-13%) and uptake (16-33%) was recorded, irrespective of nutrients, when FYM curtailed 50 to 25 t ha^{-1} coupled with increase in nitrogen from 100 to 125 kg ha^{-1}.

Key words: *Rabi* onion, FYM, Phosphorus, Nitrogen splitting, Biomass yield, Nutrient uptake, Soil available nutrients

Introduction

Onion (*Allium cepa* L.) is a significant commercial vegetable grown all over the world as a major bulb crop. It is referred to as "Queen of the kitchen" because of its highly valued flavour, aroma and distinct taste. India has the world's largest area and the second-largest producer after China. Maharashtra, Karnataka, Gujarat, Andhra Pradesh, Uttar Pradesh, Odisha, and Madhya Pradesh are mainly onion-growing states in India (Mahajan *et al.,* 2021). In 2023–2024, Punjab produced 267.33 thousand tons of onion on 11.28 thousand hectares of land, yielding an average of 237.08 quintal per hectare (Anonymous, 2025). One of the main reasons for low yield is a lack of balanced fertilisation and manuring. Verma *et al.* (2014) state that onions need a significant amount of plant nutrients and react favourably to additional nutrients. Reduced dependency on chemical fertilisers, which are expensive and harmful to the environment, is feasible only when combined with FYM to maintain high

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output levels. According to Sharma *et al.* (2012), the recovery of applied nitrogen might be as low as 30-40%, or even lower (Halvorson *et al.,* 2002). Brewster (2008) stated that the shallow rooting depth of onions and the variable soil mineral N levels before planting are the main causes of low N fertiliser recovery. Evaluating a crop's demand and when it is needed is crucial for proper N fertilizer management (Geisseler *et al.,* 2022). Nitrogen splitting had no effect on the apparent recovery rate of applied N, residual N in the soil, or anticipated N loss during the growth season. However, the total N had a substantial impact on these variables, suggesting that the two ways to reduce N loss to the environment, were to either lower the experimental recommendation system's threshold values or lower the fixed N rate prior to planting. To successfully cultivate cultivation in the state's medium-fertile alluvial soils, Punjab Agricultural University, Ludhiana has recommended 100 kg of N (50 percent basal and 50% at 30 days after transplanting (DAT)) + 50 kg of P_2O_5 (100 percent basal through single super phosphate (SSP)) and 50 kg of K_2O (100 percent basal through muriate of potash) per hectare. However, onion producers in the state must use alternative phosphorous fertilizers like di-ammonium phosphate (DAP) because SSP is expensive and difficult to get. However, in contrast to SSP, DAP offers P_2O_5 (46%) and N (18%). The time of the split N application needs to be changed since the P_2O_5 application via DAP will add about 19.6 kg of N ha^{-1} prior to onion transplanting. Second, farmers are turning to improved mineral N application by reducing the use of organic manure because of the restricted supply of FYM. Considering all of these variables, the current study was conducted to investigate how FYM dosages, phosphorus sources, and nitrogen application timing affected plant dry biomass yield, nutrient uptake, and soil availability in alluvial soil during the growing of rabi onion.

Materials and Methods

Experimental details

The experiments were conducted at the Regional Research Station, Punjab Agricultural University, Bathinda, for two consecutive seasons (rabi 2020-21 and rabi 2021-22) with the onion variety PRO-7. There were eight treatments (Table 1) replicated thrice in a randomized block design. The nitrogen was provided through urea only in treatment T_2, whereas through urea and diammonium phosphate (DAP) in other treatments (T_3 to T_8). Potassium (50 kg K_2O ha^{-1}) was provided through muriate of potash (MOP) as a basal dose in all the treatments. The seedlings of the onion variety PRO-7 were transplanted at a spacing of 15 cm × 7.5 cm in mid-January. Each plot accommodated 14 rows, and 40 plants were planted in each row.

Estimation of leaves and bulbs' dry biomass

The weight of the total harvested onion leaves and bulbs from each plot was recorded. Simultaneously, onion leaves and bulbs from ten tagged plants were collected from each plot at harvest and oven-dried at 70°C for 72 h or until weights were constant. The dry biomass of leaves and bulbs was calculated based on moisture content; yield obtained from the plot area was recorded in kg and converted to q ha^{-1}.

Table 1. Details of the *rabi* onion (PRO-7) treatments for both seasons

Treatments	Time of urea application
T_1: FYM (0) + N (0) + P_2O_5 (50 kg ha^{-1}) through SSP	-
T_2: FYM (50 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through SSP	0 & 30 DAT
T_3: FYM (50 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP	15 & 45 DAT
T_4: FYM (50 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP	30 & 60 DAT
T_5: FYM (25 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP	15 & 45 DAT
T_6: FYM (25 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP	30 & 60 DAT
T_7: FYM (25 t ha^{-1}) + N (125 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP	15 & 45 DAT
T_8: FYM (25 t ha^{-1}) + N (125 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP	30 & 60 DAT

Plant sampling and analysis

At the time of crop harvesting, leaves and bulb samples collected from each plot were dried in the shade, placed in an oven at a temperature of 70°C, ground using a Willey mill and used for further chemical analysis. Total plant N was determined by digesting it with sulfuric acid–selenium mixture, and N was analyzed using an auto-analyzer. For estimation of total P, K and S and micronutrients (Fe, Cu, Zn and Mn) 0.5 g plant samples were wet digestion using 10 ml of di-acid (HNO_3:$HClO_4$) mixture, macro-nutrients (P, K and S) and micro-nutrients (Fe, Cu, Zn and Mn) content in leaves and bulb were estimated by standard methods as described by Piper (2011). The macro-nutrient (N, P, K and S) and micro-nutrients (Fe, Cu, Zn and Mn) uptake by leaves and bulb were calculated by using the following formula : Macro-nutrient uptake (kg ha^{-1}) = [Dry matter (kg ha^{-1}) × Nutrient content (%)]¸ 100 Micro-nutrient uptake (g ha^{-1}) = [Dry matter (kg ha^{-1}) × Nutrient content (mg kg^{-1})] ¸1000. The total uptake was calculated by the sum of the leaves and bulbs' nutrient uptake.

Soil Sampling and analysis

Before final crop harvesting, 0-15 cm soil samples from 5 places of each plot were collected with the help of a soil auger, gently mixed and dried in a shed, passed through a 2-mm sieve and stored at room temperature for chemical analysis. The soil pH and EC were measured by a glass electrode using a soil-to-water ratio of 1:2. Soil organic carbon was determined by Walkley–Black method (Walkley and Black, 1934). Available N was analyzed by using standard method developed by Subbiah and Asija (1956). Available P (Olsen P) was measured using sodium bicarbonate ($NaHCO_3$) as an extractant (Olsen *et al.,* 1954). Exchangeable (available) potassium (K) was determined using the 1N ammonium acetate method (Merwin and Peech, 1951). Available S was measured using 0.15% calcium chloride ($CaCl_2$) as an extractant (Chesnin and Yien, 1950). The DTPA extractable micro-nutrients (Zn, Fe, Mn and Cu) in soil were analyzed, as the method outlined by Lindsay and Norvel (1978), using an atomic absorption spectro-photometer (Varian Model AAS FS 240).

Statistical analysis

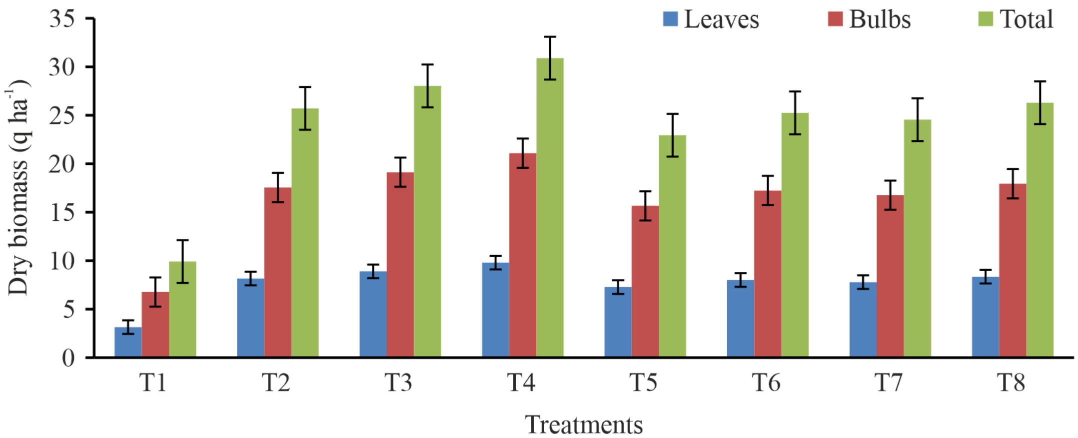
The recorded data was statistically analyzed by using Randomized Block Design (RBD) in the statistical package CPCS1software (Cheema and Singh, 1999) for pooled analysis of variance (ANOVA). The treatments were compared using the least significant difference at the 5% level of significance.

Results and Discussion

Dry biomass of leaves and bulbs

The maximum dry biomass (30.89 q ha^{-1}) was recorded with treatment T_4 included leaves biomass of 9.88 q ha^{-1} and bulbs biomass of 21.09 q ha^{-1}, which was at par with T_3 (28.03 q ha^{-1}) and significantly higher than other treatments (Fig. 1). Application of FYM @ 50 t ha^{-1} along with N @ 100 kg ha^{-1} gave the highest biomass of onion, and time of N application did not exert a significant effect. The treatments T_4 and T_3 (in which DAP is a P source) were at par with T_2 (in which SSP is a P source). The treatments T5 and T6 reduced the total dry biomass production by 18.2% and 18.3%, respectively, compared to the treatments T3 and T4, where the FYM dose was reduced from 50 to 25 t ha^{-1}. Similarly, treatments T7 and T8 reduced the total dry biomass by 12.4% and 14.9%, respectively, compared to T3 and T4, when the FYM dose was reduced from 50 to 25 t ha-1 and the N dose was increased from 100 to 125 kg ha^{-1}. Treatment T_1 registered the lowest onion dry biomass yield (9.92 q ha^{-1}), suggesting that biomass yield was greatly affected when FYM and N were not applied to the crop (Fig. 1).

The application of FYM and N in different time intervals increased the dry biomass yield, which might be attributed to an increase in the amount of nutrients in the soil, and uptake by plants, thereby increasing plant height, leaf numbers, leaf length and leaf diameter, and this leads to a higher growth rate of the crop and finally increases the dry matter. The result agrees with the findings of Negasi *et al.* (2017), Yohannes *et al*. (2017), and Gererufael et al. (2020), who stated the improvement in plant height, leaf numbers, leaf length, and leaf diameter in response to increased application of fertilizers.



T_1: FYM (0) + N (0) + P_2O_5 (50 kg ha^{-1}) through SSP- control, T_2:FYM (50 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through SSP with N application at 0 &30 DAT, T_3:FYM (50 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 15&45 DAT, T_4: FYM (50 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 30&60 DAT,T_5: FYM (25 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 15&45 DAT,T_6: FYM (25 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 30 &60 DAT,T_7: FYM (25 t ha^{-1}) + N (125 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 15&45 DAT, T_8: FYM (25 t ha^{-1}) + N (125 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 30 &60 DAT.

Fig. 1. Effect of FYM levels, phosphorus sources and time of nitrogen application on dry biomass yield of *rabi* onion leaves and bulb (pooled of 2 year)

The improvement in bulb yield and dry weight of onion bulb in response to farm yard manure and N application is possibly attributed to improved soil physical conditions and slow-release availability of nutrients, particularly N level through organic manure might have accelerated the synthesis of chlorophyll and amino acids, resulting to more translocation of photosynthesis from leaves to bulb and causing enhancement in bulb diameter and weight. This result was in line with the findings of Negasi *et al.* (2017) and Yohannes *et al.* (2017), who reported that interactions among FYM, N, and P increased onion bulb diameter and average bulb weight.

Macro and micro-nutrients content in onion leaves and bulbs

The macro-nutrients (N, P, K and S) content in leaves and bulbs varied from 1.26 to 2.57% and 1.24 to 3.21% for N, 0.23 to 0.57% and 0.29 to 0.69% for P, 1.25 to 2.38% and 1.44 to 2.67% for K, 0.24 to 0.40% and 0.24 to 0.45% for S among the treatments. Treatment T_4 had the highest N content in leaves, and the highest P and K contents in leaves and bulbs, which were at par with T3; however, T5 contained the highest bulb N content, and T2 had the highest S content in leaves and bulbs (Table 2). Table 2 revealed that leaves N content decreased by 4.7%, and leaves and bulbs P, K and S decreased by 26 and 25% (P), by 20 and 20% (K), by 13 and 12% (S) respectively, when FYM decreased from 50 t ha^{-1} to 25 t ha^{-1}. However, leaves N content decreased by 3.4%, and leaves and bulbs P, K and S decreased by 20 and 19% (P), by 15 and 15% (K), by 8 and 7% (S) respectively, when FYM dose was reduced from 50 to 25 t ha^{-1} and nitrogen dose was enhanced from 100 to 125 kg ha^{-1}. On the contrary, T_1 registered the lowest values of leaves and bulbs N (1.26 and 1.43%), P (0.23 and 0.29%), K (1.25 and 1.44%), and S (0.24 and 0.24%) content (Table 2), implying that onion growth was critically affected when FYM and N were not applied. The high N content in onion leaves and bulbs due to FYM application suggested that the crop's nutritional needs could be adequately met by mineralized nitrogen from FYM. The addition of organic manure raises the NPK content of plants because organic acids help build an organic matter complex, some of which not only alter soil pH but also combine with cations to form chelated compounds or stable complexes that aid phosphate fixation (Prabhu *et al.,* 2002). FYM may have decreased P fixation and increased P availability in soil solution for better absorption, thereby increasing P content in onion‒(Somashekar and Choudhuri, 2015). Due to their complementary actions, N and K may affect the K content of leaves and bulbs. The enhanced availability of nutrients from both native and mineralized organic manures may have contributed to the rise in K and S content by raising the concentration of K and S in the soil solution, and making it more easily absorbed (Pachouri *et al.,* 2005). These results corroborate the findings of Negi *et al.* (2022) and Yadav and Garg (2024) in onion.

Likewise, the micro-nutrients ranged from 29.86 to 80.20 and 27.42 to 75.56 mg kg^{-1} Fe, 12.31 to 27.22 and 10.77 to 24.62 mg kg^{-1} Cu, 18.49 to 43.16 and 17.25 to 40.91 mg kg^{-1}, 13.84 to 32.23 and 12.60 to 31.41 mg kg^{-1} Mn in leaves and bulbs, respectively, among the treatments (Table 2). When FYM decreased from 50 t ha^{-1} to 25 t ha^{-1}, the leaves and bulbs Fe decreased by up to 19%, Cu by up to 14 %, Zn by up to 9, and Mn by up to 12 %. Whereas when FYM decreased from 50 t ha^{-1} to 25 t ha^{-1} and N doses increased by 25%, the leaves and bulbs Fe decreased by up to 13 %, Cu by up to 10%, Zn by up to 6%, and Mn by up to 9%. The treatment T_1 showed the lowest values of Fe (29.86 and 27.42 mg kg^{-1}), Cu (12.31 and 10.77 mg kg^{-1}), Zn (18.49 and 17.25 mg kg^{-1}) and Mn (13.84 and 12.60 mg kg^{-1}) in leaves and bulbs (Table 2), implying that micronutrient content was greatly affected when FYM and N were not applied.

The organic matter can regulate the availability of heavy metals through chelation reactions, in which minerals may form stable 5- or 6-membered rings with carboxy and hydroxyl functional groups of organic aggregates, thus becoming part of the solid phase available to plants. Also, soluble organic molecules (SOM), especially low-molecular-weight organic acids, produced during the microbial decomposition of added organic materials, can complex with micronutrients (Fe, Cu, Zn, Mn) and make them more available to the growing plant. From these studies, it is evident that the application of FYM is effective in increasing micronutrient availability to plants and may enhance micronutrient content in leaves and bulbs by improving soil bulk density,

Table 2. Effect of FYM levels, phosphorus source and time of nitrogen application on macro and micro-nutrients content in onion leaves and bulb

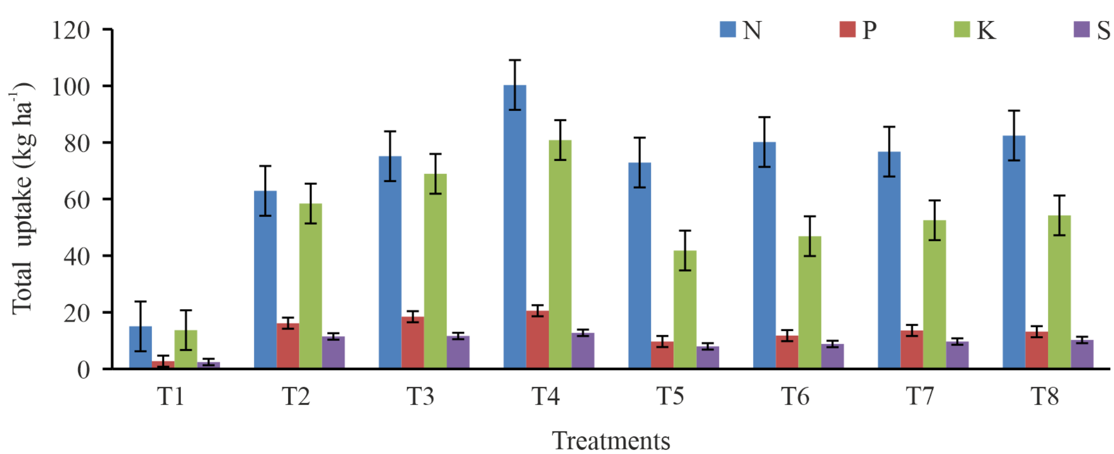
	N (%)		P (%)		K (%)		S (%)		Fe (mg kg^{-1})		Cu (mg kg^{-1})		Zn (mg kg^{-1})		Mn (mg kg^{-1})	
	leaves	bulbs	leaves	bulbs	leaves	bulbs	leaves	bulbs	leaves	bulbs	leaves	bulbs	leaves	bulbs	leaves	bulbs
T_1	1.26	1.43	0.23	0.29	1.25	1.44	0.24	0.24	29.86	27.42	12.31	10.77	18.49	17.25	13.84	12.60
T_2	2.53	2.09	0.53	0.65	2.09	2.35	0.40	0.45	71.23	67.14	25.22	22.77	40.83	38.71	29.27	28.53
T_3	2.54	2.42	0.56	0.69	2.27	2.55	0.37	0.42	74.99	70.69	26.41	23.86	42.26	40.06	30.74	29.96
T_4	2.57	3.20	0.57	0.69	2.38	2.67	0.37	0.42	80.20	75.56	27.22	24.62	43.16	40.91	32.23	31.41
T_5	2.37	3.21	0.36	0.44	1.66	1.86	0.31	0.36	54.90	51.70	21.27	19.17	36.90	34.98	25.53	24.88
T_6	2.42	3.21	0.40	0.48	1.67	1.88	0.31	0.36	57.64	54.34	21.98	19.83	38.00	36.02	26.26	25.59
T_7	2.47	3.09	0.47	0.58	1.95	2.19	0.35	0.41	68.30	64.40	24.17	21.80	40.15	38.06	28.33	27.61
T_8	2.45	3.121	0.42	0.518	1.88	2.10	0.35	0.39	63.14	59.52	23.37	21.08	38.74	36.73	27.63	26.93
CD (5%)	0.278	0.338	0.040	0.048	0.024	0.152	0.028	0.035	10.283	5.237	1.683	1.486	2.399	2.301	1.956	1.987

which supports good aeration and water-holding capacity. These results are in close agreement with those of Siag and Yadav (2004) and Shinde et *al.* (2013).

Macro-nutrients uptake by onion

The total N, P, K, and S uptake by plants between treatments ranged from 15-100 kg ha^{-1}, 2.7-20.6 kg ha^{-1}, 13.7-80.9 kg ha^{-1}, and 2.4-12.8 kg ha^{-1}, respectively. Significantly higher nutrients (N-100.3 kg ha^{-1}; P-20.6 kg ha^{-1}; K-80.9 kg ha^{-1} and S- 12.8 kg ha^{-1}) uptake was reported by T_4 followed by T_8 for N (82.4 kg ha^{-1}) uptake, and by T_3 for P (18.4 kg ha^{-1}), K (68.9 kg ha^{-1}) and S (11.6 kg ha^{-1}) uptake (Fig. 2). Irrespective of the treatments, higher nutrients uptake was reported by bulbs (N-65.5-76%, P-71.9-72.6%, K-70.3-71.1% and S-68.7-70.9%) as compared to leaves, and leaves contributed 24-34.5% N, 27.4-28.1% P, 28.9-29.7% K and 29.1-31.3 % S uptake. Treatments T5 and T6 reduced total onion N uptake by 3.1% and 20.1%, respectively, compared to T3 and T4, with a reduction in FYM dose from 50 to 25 t ha^{-1}. Similarly, T_8 reduced total N uptake by 7.9% compared to T4 when the FYM dose was reduced from 50 to 25 t ha^{-1} and the N dose was increased from 100 to 125 kg ha^{-1}. Likewise, treatment T_5 and T_6 reduced the P uptake by (90.5 and 42.8%), K uptake by (64.8 and 42.0%), and S uptake by (46.1 and 30.9%) as compared to T3 and T4, with a reduction in FYM dose from 50 to 25 t ha^{-1}. Similarly, treatment T_7 and T_8 reduced P, K, and S uptake by 26.4 and 36.0%, 23.8 and 32.9%, and 16.9 and 19.8%, respectively, compared to T3 and T4, when FYM doses were reduced from 50 to 25 t ha-1 and N doses were increased from 100 to 125 kg ha^{-1}. On the other side, T_1 registered the lowest macro-nutrients (N-15.1 kg ha^{-1}, P-2.8 kg ha^{-1}, K- 13.7 kg ha^{-1} and S- 2.4 kg ha^{-1}) uptake by onion plants.

The higher N uptake by leaves and bulbs due to the application of FYM with N fertiliser may be ascribed to the decomposition and mineralisation of manures, which ensures a better supply of available N directly to the plants, a solubilising effect on fixed forms of mineral nutrients, and a better soil physical environment. (Sreenivas *et al.,* 2000). The combination of inorganic fertilisers with organic ones resulted in a significant uptake of P by onion leaves and bulbs, which may be due to the different organic materials combined, resulting in a narrow C:N ratio, greater humification, and a more constant release of



T_1: FYM (0) + N (0) + P_2O_5 (50 kg ha^{-1}) through SSP- control, T_2:FYM (50 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through SSP with N application at 0&30 DAT, T_3:FYM (50 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 15&45 DAT,T_4: FYM (50 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 30&60 DAT,T_5: FYM (25 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 15&45 DAT,T_6: FYM (25 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 30 &60 DAT,T_7: FYM (25 t ha^{-1}) + N (125 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 15&45 DAT, T_8: FYM (25 t ha^{-1}) + N (125 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 30 &60 DAT.

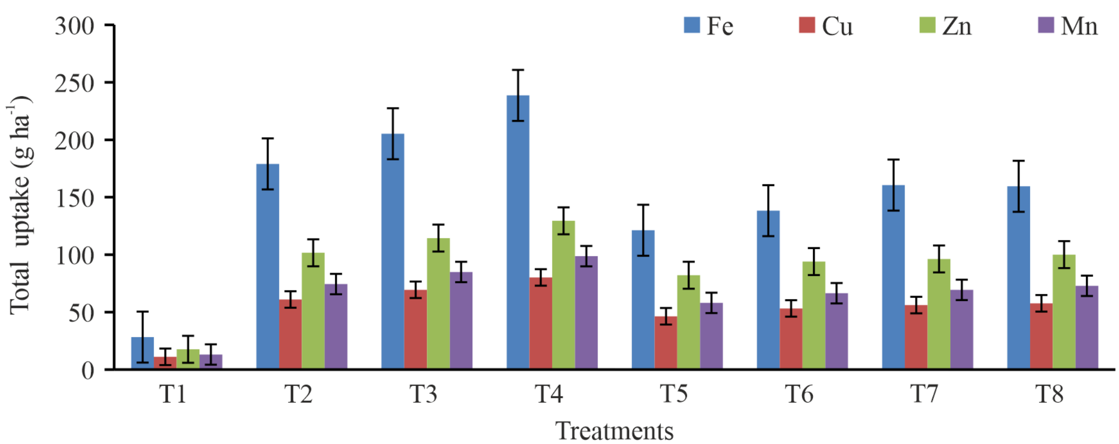
Fig. 2. Effect of FYM levels, phosphorus source and time of nitrogen application on macro-nutrients uptake by *rabi* onion leaves and bulb (pooled data of 2 year)

phosphorus in the soil (Somashekar and Choudhuri, 2015). The higher pool of available phosphorus from various organic materials contributed to improved P uptake by onion, reducing P fixation in the soil. Similarly, higher K uptake by onion leaves and bulbs also may be due to the partial acidification effect of organic manures and microflora on K-bearing minerals present in the soil. Different levels of FYM and N fertilisers significantly increase the accumulation and uptake of sulphur by onion leaves and bulbs, as higher manure levels might have increased their available content, thereby increasing their absorption and consequently increasing their content in plant tissues (Mukeshkumar *et al.,* 2000).

Micro-nutrients uptake by onion plants

Total micro-nutrient uptake by plants ranged from 28.33-238.6 g Fe ha^{-1}, 11.1-80.2 g Cu ha^{-1}, 17.7-129.5 g Zn ha^{-1} and 13.1-98.7 g Mn ha^{-1}, with higher uptake by onion bulbs as compared to leaves. The bulbs uptake higher micro-nutrients (18.9-158.8 g ha^{-1} Fe, 7.3-52.6 g ha^{-1} Cu, 11.7-87.2 g ha^{-1} Zn and 8.6-67.1 g ha^{-1} Mn) compared to leaves, and contributed up to 67.1% Fe, 66.5% Cu, 67.7% Zn and 68.4 % Mn, of total uptake (Fig. 3). Treatment T_5 and T_6 reduced the total Fe, Cu Zn and Mn uptake by 40.9 % and 42.0%, 33.2% and 33.6%, 28.3% and 27.4%, 31.7% and 32.7%, respectively, compared to T_3 and T_4, where FYM doses were reduced from 50 to 25 t ha^{-1}. Similarly, treatment T_7 and T_8 reduced the Fe, Cu, Zn and Mn uptake by 21.8 % and 33.2%, 19.2 % and 28.1%, 15.9% and 22.7%, 18.3% and 26.2%, respectively, when FYM doses were reduced from 50 to 25 t ha^{-1} with enhanced N doses from 100 to 125 kg ha^{-1}. Subsequently, minimum Fe (28.3g ha^{-1}), Cu (11.1 g ha^{-1}), Zn (17.7 g ha^{-1}) and Mn (13.1 g ha^{-1}) uptake by onion plants were reported with T_1, where no FYM and N were supplied to the crop.

The positive influence of FYM on micro-nutrients uptake by onion leaves and bulbs was due to improved nutritional environment in the root zone. Thus, adequate early supply of FYM in the crop season resulted in greater availability of nutrients in particular root zone. Nutrient availability increased in the root zone coupled with increased metabolic activity at the cellular level might have increased the nutrients uptake. The probable reason for higher micro-nutrients uptake was that, the sources of organic manures applied to onion might have improved nutrient availability in soil and thus benefited the crop. Secondly, higher dry biomass of leaves and bulb yield obtained with organic sources



T_1: FYM (0) + N (0) + P_2O_5 (50 kg ha^{-1}) through SSP- control, T_2:FYM (50 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through SSP with N application at 0 &30 DAT, T_3:FYM (50 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 15&45 DAT,T_4: FYM (50 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 30&60 DAT,T_5: FYM (25 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 15&45 DAT,T_6: FYM (25 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 30 &60 DAT,T_7: FYM (25 t ha^{-1}) + N (125 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 15&45 DAT, T_8: FYM (25 t ha^{-1}) + N (125 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 30 &60 DAT.

Fig. 3. Effect of FYM levels, phosphorus source and time of nitrogen application on micro-nutrients uptake by *rabi* onion leaves and bulb (pooled of 2 year)

Table 3. Effect of FYM levels, phosphorus sources and nitrogen application stages on soil properties and available nutrients after *rabi* onion crop

Treatments	EC dSm^{-1}	OC %	N	P	K	S	Fe	Cu	Zn	Mn
			kg ha^{-1}				g ha^{-1}			
T_1	0.40	0.35	97.1	16.0	144.2	12.9	4.78	0.44	0.78	3.76
T_2	0.33	0.43	193.2	49.7	196.6	14.7	6.31	0.61	1.07	4.99
T_3	0.30	0.43	197.8	52.5	224.3	13.2	6.36	0.61	1.08	5.02
T_4	0.29	0.45	199.6	57.3	261.5	13.6	6.50	0.61	1.09	5.13
T_5	0.36	0.39	145.0	39.3	170.3	11.7	5.93	0.54	0.99	4.62
T_6	0.34	0.41	189.2	42.1	179.7	10.9	5.83	0.52	0.97	4.53
T_7	0.37	0.39	175.7	37.6	156.3	12.6	6.19	0.54	1.01	4.87
T_8	0.38	0.37	162.7	34.3	153.2	12.2	6.05	0.53	1.00	4.72
CD (5%)	0.035	0.029	18.14	3.96	21.36	1.17	0.527	0.029	0.108	0.477
Initial	0.40	0.31	138.8	19.8	238.1	14.4	5.2	0.6	0.90	4.2

T_1: FYM (0) + N (0) + P_2O_5 (50 kg ha^{-1}) through SSP- control, T_2:FYM (50 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through SSP with N application at 0 &30 DAT, T_3:FYM (50 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 15&45 DAT,T_4: FYM (50 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 30&60 DAT,T_5: FYM (25 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 15&45 DAT,T_6: FYM (25 t ha^{-1}) + N (100 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 30 &60 DAT,T_7: FYM (25 t ha^{-1}) + N (125 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 15&45 DAT, T_8: FYM (25 t ha^{-1}) + N (125 kg ha^{-1}) + P_2O_5 (50 kg ha^{-1}) through DAP with N application at 30 &60 DAT.

also resulted in better uptake of nutrients from soil. These results are in close agreement with Gessesew *et al.* (2015).

Soil parameters

The soil pH after crop harvest showed non-significant differences among treatments (data not presented). Treatments T2 to T4 (50 t ha^{-1} FYM) showed significantly lower EC and significantly higher soil OC and macro- and micro-nutrients compared to treatments T_5 to T_8 (25 t ha^{-1} FYM). However, these treatments (T_2 to T_4) and (T_5 to T_8) were not significant when compared with each other (Table 3). The maximum soil nutrient levels (macro and micro) were recorded by T4, which was statistically comparable to T3 and T2 across all recorded nutrients (Table 3). Therefore, the application of FYM @ 50 t ha^{-1} along with N @ 100 kg ha^{-1} maintained soil fertility better, whereas the source of phosphorus (SSP or DAP) and the time of split application of nitrogen had no significant effect. It was also recorded that a reduction in FYM from 50 t ha^{-1} to 25 t ha^{-1} decreased the macro-nutrients, viz. N by 14.6%, P by 27.9%, K by 27.5%, S by 14.3%, and micro-nutrients viz. Fe by 6.1%, Cu by 12.7%, Zn by 8.1%, Mn by 7. 2%. On the contrary, T_1 registered the higher soil pH and EC and lower soil OC, macro and micro-nutrients after onion harvest (Table 3), implying that soil nutrients were greatly influenced in the absence of FYM and N application.

The results of the study suggest that the treatments did not significantly influence soil pH. The higher pH in fertilizer treated plots was probably due to the mitigating effect of the buffering capacity of the experimental soil. Shirale *et al.* (2004) reported a non-significant influence of different cropping systems and fertility levels on soil pH and EC. The increase in organic carbon content corresponding to the application of organic manures seems to be owing to the fact that these manures activate many species of soil organisms, which release phytohormones that may stimulate plant growth and absorption of nutrients (Ouda and Mahadeen, 2008). This result is consonance with the work of Sharma *et al.* (2017). It was interesting to note that the supplementation of organic sources with chemical fertilizers improved the organic carbon status of the soil. The beneficial effect of FYM on soil available macro and micro-nutrients may be ascribed to the direct addition to the available nutrient pool of soil, and release of various organic acids through FYM, which might have solubilised insoluble fractions, resulting in an increase in the concentration of soil available forms. Several scientists are of the opinion that FYM, when used as manure, enhances soil available nutrients (Ramesh *et al.,* 2017; Shahzad *et al.,* 2020).

Conclusions

The results of the present study concluded that there was 12 to 15% reduction in dry matter biomass, 5-25% reduction in macro-nutrients content and 20-36% in their uptake, 6-13% reduction in micro-nutrients content and 16-33% in their uptake was recorded with reduction in FYM dose from 50 to 25 t ha^{-1} coupled with increase in nitrogen from 100 to 125 kg ha^{-1}. The maximum dry matter biomass, macro and micro- nutrients content and uptake by *rabi* onion, and availability in soil was recorded with treatment T_4 [FYM @ 50 t ha^{-1} + N @ 100 kg ha^{-1} (at 30 and 60 days after transplanting) + P_2O_5 @ 50 kg ha^{-1} (through DAP)] and it was statistically at par with T_3[FYM @ 50 t ha^{-1} + N @ 100 kg ha^{-1} (at 15 and 45 days after transplanting) + P_2O_5 @ 50 kg ha^{-1} (through DAP)]. These two treatments, i.e. T_4 and T_3, in which phosphorus was supplied through DAP, yielded 20.1% and 9.0% higher dry matter biomass, respectively, as compared with T2, in which phosphorus was supplied through SSP.

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