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Absorption of NPK in Leaf and Bulb of Onion (*Allium cepa* L) under Varying Water Quality and Nitrogen Fertigation

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Abstract

An experiment was conducted in randomized complete block design to study the impact of varying water qualities viz. canal water (CW), poor quality saline tube well water (TW) and alternate CW and TW (CW-TW) and three N fertigation levels [100% (N_{100}), 120% (N_{120}) and 140% (N_{140}) of recommended dose of N (RDN)] under surface drip irrigation (DI) and with 120% RDN under conventional irrigation (CI) on absorption of NPK in leaf and bulb of onion (*Allium cepa* L.) at Jodhpur Farm of PAU Regional Research Station, Bathinda. The onion plants were divided into leaves and bulb at 60 days after transplanting (DAT). With the increase in irrigation water salinity a decrease in N, P and K content and nutrient uptake in both plant parts was observed. CW and TW under DI, recorded the highest and the lowest macronutrient content and uptake in leaves and bulb of onion, whereas CW-TW registered the intermediate values for these macronutrients. Fertigation of 140% RDN under DI recorded the maximum content of N, P and K in both the plant parts.CI held the significantly lower N, P and K content and uptake in both plant parts with CW, TW and CW-TW than DI at the same 120% RDN. It is concluded that assimilation of NPK in both leaves and bulb at 60 DAT was higher in DI than CI at 120% RDN, irrespective of water quality. However, cyclic use of good quality canal water and poor quality saline tube well water (CW-TW) under DI with 20% higher N fertigation than the recommended absorbed higher NPK in comparison with TW, though eventually lower than CW.

Key words: Conventional irrigation, Drip, Irrigation water quality, N fertigation, Nutrient uptake, Onion, Salinity

Introduction

Scarcity of good quality water for irrigation is becoming more of a problem day by day in arid and semi-arid regions of the world. This is particularly true in India's semi-arid northwestern area. In Punjab, 69 per cent, 25 per cent, and 6 per cent of the poor quality of ground waters are sodic, saline and saline- sodic in character, respectively. These poor quality waters are generally found in south western region of Punjab. Indiscriminate application of brackish irrigation water leads to severe health hazards thus resulting in reduced crop productivity. In these water scarce situations, irrigation through drip is a proven strategy due to less surface evaporation and runoff and minimal deep percolation (Dingre *et al.*, 2012). Also, drip irrigation (DI) systems could be utilised in conjunction with suitable crop patterns, such as increasing the area under low-water requiring vegetable crops like onion (Namara *et al.*, 2007; Pawar *et al.*, 2013).

India is first in terms of area and second in terms of onion output, after China. Punjab currently has 8,400 hectares in onion cultivation, with a total output of 1.85 lakh tonnes (Anonymous, 2022). Onions require more regular irrigation due to their shallow root zone (Bosch *et al.,* 1997; Thorup-Kristensen, 2006). It also responds well to supplementary fertilizer and requires intensive supply of N, P and K, thus the method of fertilizer application is of immense importance in increasing yields (Dumbare *et al.,* 1997; Patel and Patil, 1988). DI system can also be used for fertigation, which allows for precise and timely nutrient delivery in crops (Bar-Yosef, 1999; Gardenas *et al.*, 2005; Mailhol *et al.*, 2001). The efficient use of the nitrogen fertilizer minimizes the adverse effects of the salinity on plant growth (Abdelgadir *et al.,* 2005). The use of marginal water for irrigation through a drip system will push salts to the periphery and towards the wetting front, leaving the root zone salt-free (Dong

Table 1. Physical properties of soil profile of the experimental soil

Parameters	Soil depth (cm)	
	0-15	15-30
Sand (%)	71.3	68.4
Silt (%)	20.8	23.2
Clay (%)	7.9	8.4
Textural class	Sandy loam	Sandy loam
Bulk density (Mg m^{-3})	1.44	1.48
Field capacity (% vol.)	19.2	21.23
Permanent wilting point (% vol.)	8.21	9.1

et al., 2023). To overcome the problem of poor water quality, hindering the cultivation of salt sensitive crops like onion leading to low yields, different strategies could be devised. The conjunctive or cyclic use of poor-quality waters along with the good quality water is one such strategy to alleviate the salt stress and to overcome the good quality water shortage. Hence, an experiment was designed to evaluate the result of different irrigation water qualities and fertigation levels on nutrient uptake of the onion.

Materials and Methods

After completion of experiment in cotton – summer squash rotation for 6 years on permanent lay out using different irrigation water qualities under drip, a field experiment on onion crop under surface drip was conducted on the same set up during *rabi* season in 2022-23 at Jodhpur Farm of Punjab Agricultural University Regional Research Station, Bathinda. The site is situated at an altitude of 211 m from mean sea level, at latitude 30°09′ 36″ N and longitude 74°55′28″ E in south-western zone (IV) of Punjab. Total effective rainfall received throughout the growing season of crop was 3.5 mm and mean total evaporation recorded was 3.4 mm**.** The soil of experimental site was sandy loam in texture with alkaline reaction. The physical and chemical properties of the soil are given in the Table 1 and 2.

The good quality canal water (CW) irrigation was compared with poor quality saline tubewell water (TW; EC 3.20 to 4.21 dS m^{-1} and RSC -1.12 to 1.36 meq L^{-1}); and CW and TW in equal proportion with three N fertigation levels [100% (N_{100}), 120% (N_{120}) and 140% (N_{140}) of recommended dose of N (RDN)] under drip irrigation (DI) and with 120% RDN under conventional flood irrigation (CI). The experiment was replicated thrice in randomized complete block design (RCBD) in a plot size of 6 m × 4.20 m. Onion crop was sown in strips of 4 rows

Table 2. Chemical properties of experiment field before sowing

Characteristics	Treatments	Soil depth (0-15cm)	Methods employed
$pH_{1:2}$	CW	8.30	Beckman's glass electrode pH meter
	TW	8.52	
	CW-TW	8.38	
$EC_{1:2}$ (dS m^{-1})	CW	0.326	Solubridge conductivity meter
	TW	0.421	
	CW-TW	0.380	
Organic carbon (g kg^{-1})	CW	2.9	Walkley and Black's rapid titration method (Piper 1966)
	TW	2.2	
	CW-TW	2.4	
Available N (kg ha^{-1})	CW	151.5	Alkaline potassium permanganate method (Subbiah and Asija1956)
	TW	120.3	
	CW-TW	138.6	
Available P (kg ha^{-1})	CW	25.5	Sodium bicarbonate extractable phosphorus (Olsen *et al.* 1954)
	TW	19.2	
	CW-TW	22.1	
Available K (kg ha^{-1})	CW	303.1	Ammonium acetate extraction exchangeable potassium (Jackson 1967)
	TW	343.1	
	CW-TW	321.4	

keeping one drip lateral, with dripper spacing of 30 cm having emitter discharge of 2.4 litre h^{-1}, in between the rows for irrigation.

Dry matter (DM) production was recorded at 60 days after transplanting (DAT) by taking representative plant sample from each plot. Whole above ground onion plant portion was partitioned into different parts. The partitioned plant parts were sequentially washed with tap water, hydrochloric acid, distilled water and deionized water in plastic containers. They were air dried in shade and then subjected to drying at 60-70 °C until a constant dry matter content was achieved. A known weight of the leaf and bulb sample taken at 60 DAT was digested with sulphuric acid for determination of N and with di-acid mixture of nitric acid and perchloric acid in ratio of 3:1 for analysis of P and K. The total N was analysed using the Kjeldahl method whereas total P and K were determined by Vanadomolybdo phosphoric yellow colour method and flame photometer, respectively. The NPK uptake of partitioned plant parts was calculated by using the formula:

Nutrient uptake (kg ha^{-1}) =[Nutrient content (%) × Dry matter production (kg ha^{-1})]/100

Statistical analysis

The data was analysed using SAS (Statistical Analysis System) for analysis of variance (ANOVA) to determine the statistical significance of treatments effect.

Results and Discussion

Nutrient content in plant parts

The effect of different IWQ along with varying N fertigation levels (100%, 120% and 140% of RDN) on NPK content in leaf and bulb of onion was determined at 60 DAT. It was observed that leaf recorded higher N content than bulb (Table 3). The highest N content was registered with CW which varied significantly in both bulb and leaf. CW-TW treatment held intermediate values of N content. The N content in leaf and bulb increased significantly with increment in N dose. N content in treatment N_{140} under DI was found to be significantly higher than all other doses in both plant parts. The interaction of drip (DI) and conventional irrigation (CI) was also found to be significant. The% N content in leaf and bulb with CW, TW and CW-TW combined with N_{120} under DI was significantly higher than% N recorded under CI in both plant parts.

The data presented in Table 4 revealed that the highest concentration of P was found in the leaf in comparison with bulb. The maximum% P was registered with CW treatment in both leaf (0.52%) and bulb (0.32%) which was significantly higher than all other treatments. Increasing N doses also revealed significant results where the highest P content was recorded with 140% RDN (N_{140}) which was at par with 120% RDN (N_{120}) in case of bulb. IWQ yielded non- significant effects

Table 3. Effect of irrigation water quality and N levels on nitrogen content (%) in onion leaves and bulb at 60 DAT

Irrigation water quality	N levels				
	N_{100}	N_{120}	N_{140}	Mean	C_{120}
Leaf					
CW	1.63	1.80	1.93	1.79	1.48
TW	1.30	1.33	1.39	1.34	1.41
CW-TW	1.62	1.45	1.58	1.55	1.39
Mean	1.52	1.53	1.63		
LSD (0.05): I=0.075; N= 0.075; IxN= 0.130; C=NS ; CxT=0.074					
Bulb					
CW	0.94	0.95	1.25	1.05	0.76
TW	0.42	0.62	0.66	0.57	0.56
CW-TW	0.66	0.68	0.73	0.69	0.71
Mean	0.67	0.75	0.88		
LSD (0.05): I=0.059; N= 0.059; IxN=0.101 ; C=NS ; CxT= 0.103					

*C_{120}- conventional flood irrigation at 120 % RDN (120% RDN under DI is equivalent to 100% RDN in conventional method)

Table 4. Effect of irrigation water quality and N levels on phosphorus content (%) in onion leaves and bulb at 60 DAT

Irrigation	N levels				
water quality	N_{100}	N_{120}	N_{140}	Mean	C_{120}
			Leaf		
CW	0.47	0.49	0.58	0.52	0.43
TW	0.32	0.33	0.35	0.33	0.31
CW-TW	0.35	0.40	0.42	0.39	0.39
Mean	0.38	0.41	0.45		
LSD (0.05): I=0.024; N= 0.024; I×N= NS; C= NS; C×T= 0.02					
			Bulb		
CW	0.29	0.31	0.35	0.32	0.26
TW	0.23	0.26	0.26	0.25	0.25
CW-TW	0.26	0.28	0.32	0.29	0.26
Mean	0.26	0.28	0.31		
LSD (0.05): I=0.028; N= 0.028; I×N= NS; C=NS ; C×T= 0.02					

*C_{120}- conventional flood irrigation at 120 % RDN

under CI. However, the interaction of DI and CI was found to be significant. DI resulted in significantly higher% P content in leaf and bulb at 120% RDN with CW as compared to CI. The P content with CW-TW at 120% RDN under DI was found to be at par with CI in both plant parts. However, when the dose was increased to 140% RDN in DI, P content was found to be significantly higher than CI.

The similar trend was observed in K concentration where leaves accumulated the highest K content (Table 5). The highest N fertigation dose (N_{140}) gave maximum K content in both the parts as compared to N_{100} and N_{120}. It was observed that the CW recorded the maximum K content in leaf (4.87%) and bulb (2.70%) which was significantly higher than CW-TW and TW. Cumulative interaction of N dose and IWQ yielded significant results. The average K content under CI was found to be maximum with CW which was statistically at par with CW-TW in leaves. CW under DI registered the maximum K content in the leaves which was significantly higher than CI. In case of bulb, K content with CW under DI was significantly higher than conventional method but K content under TW and CW-TW at 120% RDN was found to be at par with CI. However, when the N dose was increased to 140% RDN, DI resulted in significantly higher K content than CI.

Table 5. Effect of irrigation water quality and N levels on potassium content (%) in onion leaves and bulb at 60 DAT

Irrigation	N levels				
water quality	N_{100}	N_{120}	N_{140}	Mean	C_{120}
			Leaf		
CW	4.75	4.82	5.03	4.87	4.74
TW	3.45	4.09	4.53	4.03	3.00
CW-TW	4.67	4.73	4.76	4.72	4.41
Mean	4.29	4.55	4.77		
LSD (0.05): I=0.113; N= 0.113; I×N= 0.195; C= 0.376; C×T= 0.145					
			Bulb		
CW	2.37	2.56	3.17	2.70	2.32
TW	1.83	2.00	2.05	1.96	1.95
CW-TW	2.01	2.05	2.14	2.07	2.06
Mean	2.07	2.20	2.45		
LSD (0.05): I=0.092; N= 0.092; I×N= 0.159; C=0.168 ; C×T= 0.06					

*C_{120}- conventional flood irrigation at 120 % RDN

The decrease in NPK content in both the partitioned plant parts in TW may be attributed to ionic imbalance as a result of increasing irrigation water salinity at the initial growth stage of plant development. Mansour *et al.* (2005) and Zhang *et al.* (2014) also reported that the access to nutrients and transportation within the plants is restricted due to ionic imbalance as irrigation water salinity causes Na^+ and Cl^- ions to compete with nutrients like Ca^{2+}, K^+ and NO_3^- and leads to reduction in NPK concentrations in roots and leaves. The increasing N levels increased the nutrient availability near the root zone hence leading to increased nutrient content in the plant parts. The higher N content under the DI system could be attributed to the better moisture regimes around the root zone which enhances the movement of nitrate towards the roots and the reduced leaching losses in comparison to CI. These results are in line with Encisco *et al.* (2015). However, absolute values of P content in both the partitioned plant parts continued to increase with N increments. This might be due to enhanced availability of the P in the root zone as a result of increased root proliferation due to frequent N application.

Nutrient uptake by plant parts

The NPK uptake by both the plant parts (leaf and bulb) was also significantly affected by different IWQ and varying levels of N at 60 DAT (Table 6 to 8) and followed the similar trend as that of NPK content in plant parts. The NPK uptake decreased with increasing levels of salinity. The maximum NPK uptake by leaf and bulb was recorded with CW which was significantly higher than TW and CW-TW under DI. Increasing N levels also significantly increased the nutrient uptake by both plant parts. The maximum level of N (N_{140}) registered the maximum NPK uptake followed by CW-TW and TW. These results are in conformity with Kemal (2013) and AlSolaimani and Basahi (2002) who documented the increase in the N uptake with increasing N levels. The sufficient soil moisture enhanced the movement of nitrates towards the plant roots facilitating the higher uptake of applied N dose. The increased N availability led to the better root growth and hence the increased uptake of P and K (Bhatti *et al.*, 2019). The cumulative effect of IWQ and N levels had significant effect on nutrient uptake except for P uptake in bulb and K uptake in leaf. The nutrient uptake was higher in leaves than bulb. Under CI also, the maximum NPK uptake was observed with CW in both plant parts. However, the NPK uptake by leaf with CW was found to be statistically at par with CW-TW. CW with 120% RDN (N_{120}) under DI produced significantly higher NPK uptake in leaf and bulb in comparison to CW under CI with same N dose. Even TW treatment at 120% RDN under DI recorded 30.4%, 30% and 29.7% higher N,P and K uptake, respectively in bulb as compared to CI. The higher nutrient uptake in DI as compared to CI could be

Table 6. Effect of irrigation water quality and N levels on nitrogen uptake (kg/ha) by onion leaves and bulb at 60 DAT

Irrigation water quality	N levels				
	N_{100}	N_{120}	N_{140}	Mean	C_{120}
			Leaf		
CW	17.8	25.2	27.8	23.6	13.1
TW	11.6	12.9	13.4	12.6	8.0
CW-TW	14.7	16.1	21.2	17.3	12.9
Mean	14.7	18.1	20.8		
LSD (0.05): I=1.62; N= 1.62; I×N= 2.81; C=3.03 ; C×T=1.17					
			Bulb		
CW	6.2	6.6	9.4	7.4	4.0
TW	2.6	3.0	3.4	3.0	2.3
CW-TW	3.9	4.2	4.9	4.3	2.7
Mean	4.3	4.6	5.9		
LSD (0.05): I=0.33; N= 0.33; I×N=0.58 ; C=0.61 ; C×T= 0.23					

*C_{120}- conventional flood irrigation at 120 % RDN

Table 7. Effect of irrigation water quality and N levels on phosphorus uptake (kg ha^{-1}) by onion leaves and bulb at 60 DAT

Irrigation water quality	N levels				
	N_{100}	N_{120}	N_{140}	Mean	C_{120}
			Leaf		
CW	5.2	6.9	8.4	6.8	4.4
TW	2.8	2.9	3.2	3.0	2.6
CW-TW	3.2	4.1	5.3	4.2	3.5
Mean	3.7	4.6	5.6		
LSD (p=0.05): I=0.37; N= 0.37; I×N= 0.63; C=0.75 ; C×T=0.29					
			Bulb		
CW	1.9	2.2	2.6	2.2	1.5
TW	1.2	1.3	1.3	1.2	1.0
CW-TW	1.5	1.7	2.1	1.8	1.4
Mean	1.5	1.7	2.0		
LSD (p=0.05): I=0.15; N= 0.15; I×N=NS ; C=0.27 ; C×T= 0.10					

*C_{120}- conventional flood irrigation at 120 % RDN

Table 8. Effect of irrigation water quality and N levels on potassium uptake (kg ha^{-1}) by onion leaves and bulb at 60 DAT

Irrigation water quality	N levels				
	N_{100}	N_{120}	N_{140}	Mean	C_{120}
			Leaf		
CW	51.9	67.7	72.5	64.0	44.5
TW	31.5	39.7	42.1	37.8	26.2
CW-TW	42.4	52.5	63.6	52.8	39.8
Mean	41.9	53.3	59.4		
LSD (p=0.05): I=3.67; N= 3.67; I×N= NS; C=7.56 ; C×T=2.91					
			Bulb		
CW	15.6	17.8	23.7	19.0	13.1
TW	8.4	9.6	10.5	9.5	7.4
CW-TW	11.9	12.6	14.2	12.9	7.9
Mean	12.0	13.3	16.1		
LSD (p=0.05): I=0.74; N= 0.74; I×N=1.29 ; C=1.80 ; C×T= 0.69					

*C_{120}- conventional flood irrigation at 120 % RDN

attributed to the better soil moisture regimes in drip even under saline conditions which enhanced the nutrient uptake. The N, P and K uptake by leaf and bulb of onion is depicted in Figure 1(a), 1(b) and 1(c), respectively.

Conclusion

From the study conducted, it can be concluded that increasing salinity of irrigation water reduced the concentration and the uptake of macronutrients- nitrogen (N), phosphorus(P), and potassium (K) in both the partitioned plant parts. Irrigation with good quality water (CW) accumulated maximum nutrient content in plant parts followed by CW-TW both under DI and CI. Increasing N levels significantly increased the nutrient content and uptake by plant parts. The highest dose of N (N_{140}) led to the maximum N, P and K content and uptake in leaf and bulb. DI was found to be superior in comparison with CI even with poor quality saline irrigation water. DI registered significantly higher nutrient content and uptake by plant than conventional irrigation method. However, cyclic use of good quality canal water and poor quality saline tube well water (CW-TW) under DI with 20% higher N fertigation than the recommended absorbed higher NPK in comparison with TW.

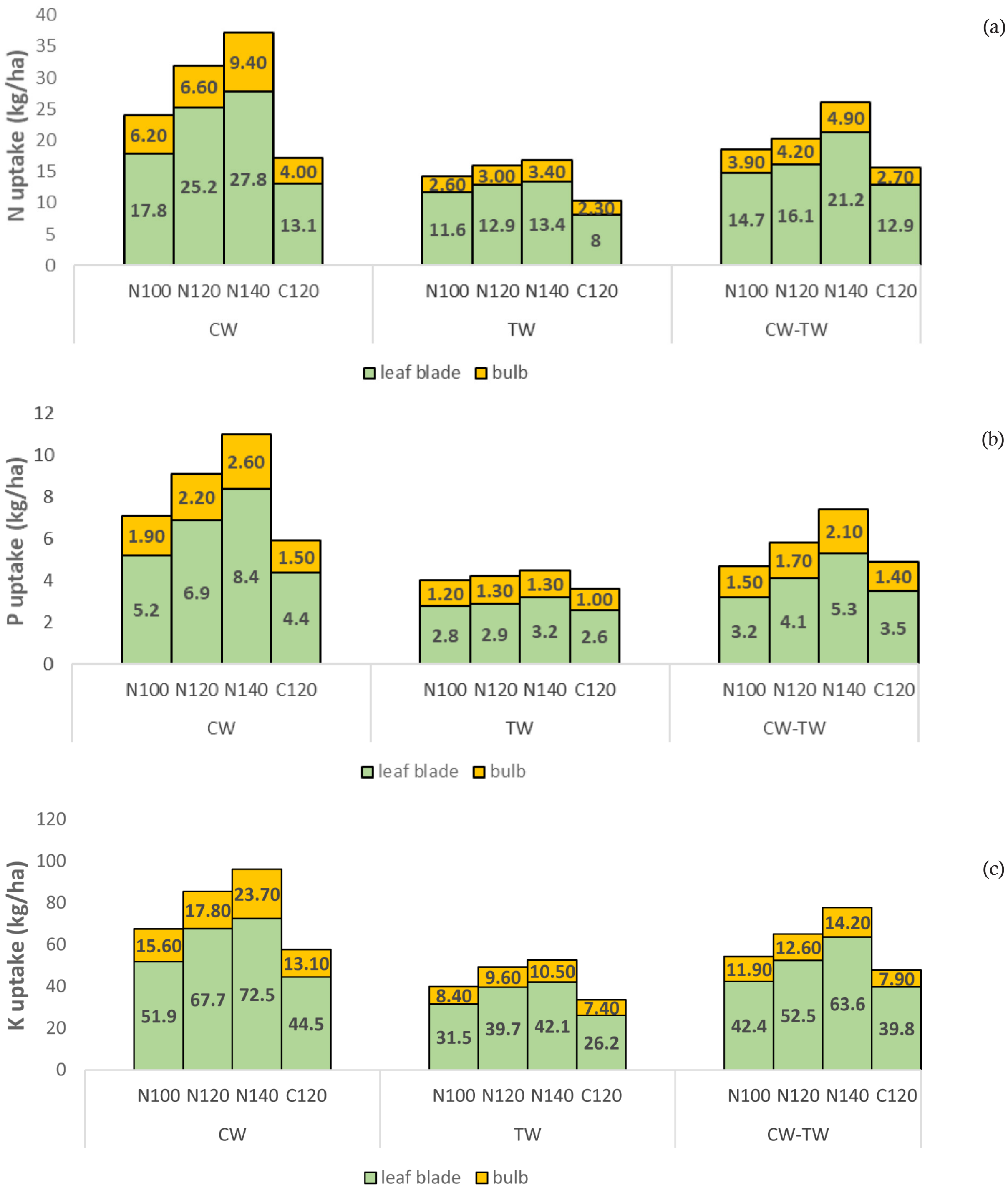

Fig. 1 Uptake (kg/ha) of (a) N (b) P and (c) K by onion leaf and bulb at 60 DAT

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