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Response of onion (*Nasik red*) to nitrogen, potassium and sulphur fertilization under arid western conditions of Rajasthan

RK Bairwa, RK Narolia, CK Dotaniya and Neetu Bairwa

Abstract
The onion (*Nasik Red*) field study, which comprised 10 different treatments laid out in a split plot design with three replications at ARS-SKRAU, Beechwal, Bikaner Zone Studies, clearly showed that application of inorganic fertilizer's at N, K and S levels significantly increased all the growth, yield and quality characters *viz.* Shelf life, TSS, Allyl propyl disilphide of onion. Similarly, N levels of @ 80 kg N ha^{-1} (soil application) + 20 kg N ha^{-1} (4 foliar sprays) produced the highest bulb yield (227.62 q ha^{-1}), closely followed by N_2 (210.45 q ha^{-1}) and N fertilization @ 80 kg N ha^{-1} (soil application) + 20 kg N ha^{-1} (4 foliar sprays), which was significantly higher than control. Application of 80 kg N and K ha^{-1} (soil application) + 20 kg (4 foliar sprays) and 40 kg sulphur ha^{-1} produced a significantly superior crop, and this treatment combination was recommended for maximum bulb production of onion.

Keywords: Growth, yield, shelf life, TSS, allyl propyl disilphide, Nasik red

Introduction

Onion (*Allium cepa* L.) is one of the most important vegetable bulb crops produced in India. Growth and yield productivity of the crop has been far below the regional and national standards owing to several factors; absence of location specific fertilizer recommendation being the major among others. Onion is the most important commercial bulbous crops cultivated extensively in India and widely used as vegetables in our country (Bairwa *et al.*, 2020) [8]. It belongs to family Alliaceae. The chief component of pungency in onion is 'allyl propyl disulphide' Onion contains carbohydrates (11.0g), proteins (1.2g), fiber (0.6g), moisture (86.8g), and several vitamin and like vitamin A (0.012 mg), vitamin C (11 mg), thiamine (0.08mg), riboflavin (0.01mg), and niacin (0.2mg), and also some minerals like phosphorus (39mg), calcium (27 mg), sodium (1.0 mg), iron (0.7mg), and potassium (157 mg), per 100 g (Rahman *et al.*, 2013) [52]. India is the second largest producer of onion in the world and occupies 1.64 Million Hectares area with a production of 26.83 Million Tonnes and yield 16360 Kg. /Hectare (Anonymous 2021-22).

Mineral nutrition is main that affects growth, yield and quality of onion (Chung 1989) [16]. Nitrogen and phosphorus and potassium are often referred to as the primary macronutrients because of the probability of plants being deficient in these nutrients and because of the large quantities taken up by plants from the soil relative to other essential nutrients (Marschner 1995) [43]. Nitrogen comprises 7% of total dry matter of plants and is a constituent of many fundamental cell components (Bungard *et al.*, 1999) [13]. It is one of the most complexes in behavior, occurring in soil, air and water in organic and inorganic forms. For this reason, it poses the most difficult problem in making fertilizer recommendations (Archer 2002) [5]. Dotaniya *et al.* (2022) [20] application of FYM @ 20t ha^{-1} to maize followed by FYM @ 5t ha^{-1} to chickpea increased the productivity and nutrient uptake in chickpea, improved soil physico-chemical properties and reflected as viable technique in improving soil nutrient availability on sustainable basis. Plant demand for N can be satisfied from a combination of soil and fertilizer to ensure optimum growth. It is one of the most complexes in behavior, occurring in soil health, air and water in organic and inorganic forms (Dotaniya *et al.*, 2019 and Dotaniya *et al.*, 2020) [22, 18]. For this reason, it poses the most difficult problem in making fertilizer recommendations (Archer 2002 and Dotaniya *et al.*, 2020) [5, 18]. Plant demand for N can be satisfied from a combination of soil and fertilizer to ensure optimum physiological growth.

Phosphorus application P to legumes plays a key role in formation of energy rich bonds, phospholipids and for development for root system (Pingoliya *et al.*, 2015) [50].

Phosphorus increased chickpea grain yield and other quality parameters in legumes such as protein and amino acids (Dotaniya *et al.,* 2014) [24]. Apart from P, iron (Fe) plays an important role in chlorophyll synthesis, being a structural component of hemes, hematin and leg hemoglobin. It is also an important part of the enzyme nitrogenase, which is essential for the N_2 fixation in legumes (Kumar *et al.,* 2009) [37].

Potassium (K) is a major plant nutrient, which is needed by the plants in large amount and is supplied by the K fertilizers (Dotaniya *et al.,* 2020) [18]. It is available to the plants in the form of cation (K^+). Actually potassium is essential for a variety of process *i.e.,* photosynthesis, fruit formation, winter hardiness and disease resistance. It stiffens straw and thus reduces lodging, and plays an important role in protein formation especially in grain filling (El-Tohamy *et al.,* 2011) [28]. It was reported by many researchers that they increased the plant growth, nutrient uptake and plant yield as well as quality (Karakurt *et al.,* 2009) [35]. Sulphur is an essential plant nutrient and plays a vital role in biosynthesis of certain amino acids (Cysteine, cystine and methionine) and also helps in the synthesis of co-enzyme and formation of chlorophyll and nitrogenizes enzyme. Sulphur is reported from two natural growth regulators *viz.,* thiamine and biotin. Sulphur plays an important role in chlorophyll formation because it has been observed that sulphur deficient soil and plants contain as 40 to 60% in comparison with those receiving normal amounts of this elements (Dharwe *et al.,* 2019 and Malvi *et al.,* 2019) [17, 41]. Sulphur occurs in glutathione that is important to oxidation reduction reaction. Sulphur has been recognized as an important nutrient for higher yield and quality of onion bulbs. Sulphur is essential for building up sulphur containing amino acids and also for a good vegetative growth and bulb development in onion (Gondane *et al.,* 2018) [29]. The largest changing trends in agricultural, yield target concept and fertilizer recommendation for maximum profit per hectare become more promising. Yield target concept has the added advantage in which target can be fixed by taking into consideration the resources available. Therefore, it is essential to find out the best and optimum level of sulphur for soil application and its effect on yield and quality of onion (Gondane *et al.,* 2018) [29].

Method and Materials

A present field experiment was carried out at the Instructional Farm, College of Agriculture, S.K. Rajasthan Agricultural University, Bikaner, during *Rabi* season for the 2016–17 and 2017-18 years to find out the effects of inorganic fertilizer, organic manure and fertilizers on the nutrient content, growth and yield attributes of the Nasik red variety of onion crop. The treatment details and their symbols is N_1- (control), N_2 - 100 Kg N ha^{-1} (soil application), N_3- 80 kg N ha^{-1}(soil application) +20 kg N ha^{-1}(4 foliar sprays), N_4- 60 kg N ha^{-1} (soil application) + 20 kg N ha^{-1}(4 foliar sprays), K_1- (control), K_2 - 100 kg K ha^{-1} (soil application), K_3- 80 kg K ha^{-1} (soil application) + 20 kg K ha^{-1}(4 foliar sprays), K_4- 60 kg K ha^{-1}(soil application) + 20 kg K ha^{-1} (4 foliar sprays) and S_1- (control), S_2- 40 kg S ha^{-1} (soil application) was applied. N and K fertilization control levels (100, 80 (20-4 foliar sprays), 60 (20-4 foliar sprays), and S fertilization control (40 kg ha1) were used. The geographically, is climate of this zone is typically arid characterized by acridity of the atmosphere and salinity in the rhizosphere with extreme temperature both in summer and winters and their transitions are characterized with abrupt fall and rise in temperature. The annual average rainfall of this region is about 200-300 mm which is mostly received from the south-west monsoon during the crop period of July to September. The mechanical composition of the composite soil sample was determined by Piper (1950) [51], physico-chemical properties such as bulk density (Jackson 1973) [32], soil pH and EC (Meena *et al.,* 2020) [44], organic carbon by the Walkley and Black's method (Kumar *et al.,* 2018) [38], calcium carbonate by hut chins on the rapid titration method (Piper 1950) [51], estimation of available N, P, and K (Jackson 1973) [32], and The experimentally recorded data was analysed statistically using the analysis of variance technique of the split plot design suggested by (Panse and Sukhatme 1985) [49].

Total soluble solids (%)

Total soluble solids (TSS) was determined with the help of hand refract meter at the time of harvesting of bulb and final TSS measured after adding and / or substrate the correction values from table at 20 °C.

Allyl propyl disulphide (mg g^{-1})

Allyl propyl disulphide content in onion bulb was determined as pyruvic acid (μ mol/g) by the procedure followed by (25).

Ally-propyl disulphide

$$= \frac{\text{Pyruvate content from standard curve } (\mu \text{ mol})}{\text{Alliquate of test control solution taken colour devlopment (ml)}} \times \frac{\text{Total volume of solution of sample made (g)}}{\text{Wt.of sample taken for assay (g)}}$$

Shelf life

Onions are stored at room temperature in a dark and dry place with plenty of air circulation to determine shelf life. A hanging wire mesh net (mesh bags and paper bags) are used.

Results and Discussions

Growth attributes

Different N fertilization increased like number of leaves plant^{-1} at 30, 60 and 90 DAT (Table 1) (days after transplanting), plant height (Table 2) and fresh and dry weight (Table 3) of leaves at 90 DAT and showed that application of N_3 increased the growth attributes which was significantly higher over control, N_1 and N_2. The maximum plant height at 30, 60 and 90 DAT (19.24, 37.01 and 47.28 cm, respectively) was recorded with treatments N_3, while minimum was under control *i.e.* N_1 (16.01, 30.76 and 39.18 cm, respectively). The corresponding increase in plant height under N_3 was to the tune of 20.17, 5.39 and 4.56 per cent at 30 DAT, 20.32, 2.54 and 3.17 per cent at 60 DAT and 20.67, 3.96 and 4.16 per cent at 90 DAT over N_1 (control), $N_2$and N_3, respectively. The maximum plant height at 30, 60 and 90 DAT was 18.91, 36.03 and 46.01 cm, respectively with K_3 treatment, while minimum (17.06, 32.90 and 41.63 cm) was under control (N_1) respectively. Maximum plant height of (18.63, 35.86 and 45.22 cm) was recorded at 30, 60 and 90 DAT under S_2 (40 kg S ha^{-1} soil application) which was significantly superior to S_1 (control) on pooled basis. The increment of onion plant vegetative parameters with the addition of higher level of N might be attributed to more availability of nutrients, especially N, which enhanced the number of leaves by its simulative effect on cell division and cell enlargement that in turn might increase number of leaves and leaf dimensions. Also enhanced protein synthesis leading to an increase in building up of carbohydrates and this in turn result in increased in plant growth characters. Bungard, *et al.* (1999) [13] stated that N is a constituent of many fundamental cell components and it plays a vital role in all living tissues of the plant. No other element has such an effect on promoting vigorous plant growth. Also, the improvement of fresh and dry weight of whole onion plant could be attributed to an increased photosynthetic area in response to N fertilization that enhanced assimilates production and partitioning in the plants. The obtained results are in conformity with the findings of (Nasik red) onion (Abdissa *et al.*, 2011 and Shaheen *et al.*, 2011) [1, 55].

The plant height, number of leaves per plant at 30, 60 and 90 DAT and fresh and dry weight of leaves at 90 DAT. Application of 80 kg K ha^{-1}(soil application) + 20 kg K ha^{-1} (4 foliar sprays) recorded highest plant growth attributes which was significantly higher over control, K_2 and K_4 soil and foliar application. Vegetative growth parameters *viz.* plant height (18.91, 36.03 and 46.01 cm), number of leaves per plant (4.88, 6.16 and 7.12) at 30, 60 and 90 DAT and fresh and dry weight of leaves (12.77 and 3.00 g) at 90 DAT were recorded of K_3, while as compared to control. Role of K which took active rate in metabolism and many processes needed to sustain and promote plant vegetative growth and development. Linking potassium (K) balance to soil fertility creates a valuable indicator for sustainability assessment in agricultural land-use systems. It is crucial for the efficient use of K resources and resource sustainability to realize soil K balance status in India (Dotaniya *et al.*, 2022a) [23]. Moreover, K plays a major role in many physiological and biochemical processes such as cell division and elongation and metabolism of carbohydrates and protein compounds (Marschner 1995) [43]. Potassium foliar application increases the outward translocation of photosynthetic from the leaf (Ashley and Goodson 1972) [6]. The higher number of leaves per plant (11.56, 11.68), weight of bulb (50.42 from 51.83 g) and bulb yield (226.66 from 227.66 q ha^{-1}) with increasing levels of K application from 100 to 150 kg ha^{-1}. Nandi, *et al*. (2002) [46] also reported that as there is a significant difference among the fertilizer doses with respect to onion plant height. Plants were the tallest when 90 kg N and 120 kg K_2O ha^{-1} were applied.

Plant growth parameters *i.e*. plant height, number of leaves per plant, at 30, 60 and 90 DAT and fresh and dry weight of leaves at 90 DAT and showed that application of 40 kg S ha^{-1} (soil application) increased the plant growth parameters which was significantly higher over control. However, the highest vegetative growth parameters *viz.* the plant height (18.63, 35.86 and 45.22 cm), number of leaves per plant (5.06, 6.41 and 7.26) at 30, 60 and 90 DAT and fresh and dry weight of leaves (12.05 and 2.83 g) at 90 DAT were recorded under 40 kg S ha^{-1} (soil application), whereas minimum in control. The obtained results are in conformity with those of Abou-El-Nasr and Ibrahim (2011) [2] found that increasing K levels increased growth attributes weight basis. This might be ascribed to adequate supply of sulphur that resulted in higher production of photosynthesis and their translocation to sink, which ultimately increased the fresh yield of onion. Increasing sulphur availability has been associated with increasing bulb weight (Lancaster *et al.*, 2001) [39]. Similarly report has been reported by (Josephine *et al.*, 2006) [33].

Yield Parameters

The nitrogen fertilization of @ 80 kg N ha^{-1} (soil application) + 20 kg N ha^{-1} (4 foliar sprays), recorded highest bulb yield (227.62 q ha^{-1}), which were closely followed by N_2 (210.45 q ha^{-1}) which was significantly higher over control (Table 2). Similarly, there is a reported that an application of 125 kg N ha^{-1} showed higher yield when as compared with control. The N application of *i.e.* N_3 significantly increased the total bulb yield as compared to other N levels as well as control. Balanced nutrient application of macro and secondary nutrient application gave significant higher marketable yield and yield attributing characters. Different potassium fertilizations significantly maximum bulb yield (218.21q ha^{-1}) was obtained when onion was grown with K_3 80 kg K ha^{-1}(soil application) +20 kg K ha^{-1}(4 foliar sprays) followed by K_2 *i.e.*100 kg K ha^{-1}(soil application) and K_4 *i.e.* 60 kg K ha^{-1}(soil application) +20 kg K ha^{-1} (4 foliar sprays), while minimum under K_1 (151.47 q ha^{-1}). The increase in bulb yield of onion was found to be 44.06 per cent higher with K_3 over control followed by 4.89 and 6.99 per cent with K_2 and K_3 on pooled basis. Sulphur S_2 (40 kg S ha-1(soil application)) significantly increased bulb yield (208.61 qha^{-1}) which was significantly higher (182.23 qha^{-1}) over S_1 (control) on pooled basis. The percent increase in bulb yield ha^{-1} with treatment S_2 was to the tune of 14.47 percent over S_1 (control). Maximum bulb yields with increase in N application from 100 to 150 kg ha^{-1} (Vachhani and Patel 1993) [58]. Similarly, a study (Kumar *et al.*, 2001) [36] observed that the increase in N application significantly increased the dry weight of tops and bulbs, bulb diameter, 100 bulb weight and bulb yield up to 80 kg ha^{-1} urea. Application of vermicompost (300 gm/pot) resulted in significantly higher nitrogen phosphorus and potassium growth and yield of fenugreek than FYM, Rhizobium treatment and control (Dotaniya *et al.*, 2019) [22]. Application of increased levels of sulphur up to 30 kg S/ha recorded significantly highest seed yield of mungbean and sesame (Doutaniya *et al.*, 2021) [26]. Similarly, there is a report that potassium application of 125 kg ha^{-1} showed higher fresh and dry weight of bulb, volume of bulb, number of scales per bulb and bulb diameter when as compared with control (Hariyappa 2003). This finding are in line with the results that the higher weight of bulb and bulb yield with increase in potassium application from 100 to 150 kg ha^{-1} (Vachhani and Patel 1993) [58]. The combined application of 40 kg sulphur ha^{-1} and 30 x 30 cm spacing was found suitable in terms of yield, net return 1,93,239 (Rs ha-1) and B:C ratio (2.21) over control with 45 x 45 cm spacing, respectively and resulted in saving of 20 kg sulphur ha^{-1}. Thus, application of sulphur 40 kg ha-1 along with 45 x 30 cm spacing recommended for knol-khol crop (Bairwa *et al.*, 2017 & 2017a) [9-10]. The above research findings are close in conformity with the earlier findings given by (Mishu *et al.*, 2013) [45]. Malvi *et al.* (2021) [42] application of 40 kg S/ha significantly influenced by protein and total uptake of fodder berseem over control. The improvement in yield may be due to higher uptake of N, P, K and S by the onion crop resulting higher chlorophyll, increased enzymatic and protein synthesis, proper root proliferation, and enhancing the translocation of assimilates research findings are close in conformity with the earlier findings given by onion and others crops (Yadav *et al.*, 2015 and Salame *et al.*, 2020) [59, 54].

Quality parameters

Demonstrated that the quality and nutritional values of onion bulb, *i.e.* TSS (^{0}B) and allyl-propyl disulphide content was significantly influenced by N fertilization Shelf life of onion bulb at ambient the room temperature was not influenced significantly by nitrogen levels in both the seasons (Table 4). Quality and nutrient content in onion bulb tissues significantly improved when onion plants received a nitrogen levels N_3 when compared with the control, N_2 and N_4 soil application +foliar sprays in both seasons of study. Application of N fertilization of N_3 gave significantly highest values of TSS (10.57 ^{0}B) and allyl-propyl disulphide content (7.59 mg g^{-1}) while, the lowest values were obtained with control. The maximum shelf life of onion bulb at ambient a room temperature (167.70 days) was recorded with control treatment, followed by N_4 (167.53 days) and N_3 (164.73 days) treatment. Whereas, minimum (164.06 days) was found in *i.e.* 100 kg N ha^{-1}(soil application).

Quality parameters of onion bulb like TSS (^{0}B) and allyl-propyl disulphide content was significantly influenced by the application of different levels of K fertilizers. Shelf life of onion bulb at ambient a room temperature was not influenced significantly due to potassium levels in both seasons. Quality and nutrient contents in onion bulb tissues were significantly increased when onion plants received a potassium fertilization *i.e.* K_3 when compared with the control, K_2 and K_4 soil and foliar application in both seasons of study (Table 4). Application of K_3 fertilization of 80 kg K ha^{-1}(soil application) + 20 kg K ha^{-1} (4 foliar sprays) gave significantly the highest values of TSS (10.48^{0}B) and allyl-propyl disulphide content (7.47 mg g^{-1}). While, the lowest values (9.93 ^{0}B and 6.96 mg g^{-1}) were obtained with control. The maximum shelf life of onion bulb at ambient room temperature (168.74 days) was recorded at *i.e.* 100 K kg ha^{-1}(soil application) treatment, followed by K_4 (165.68 days) and N_4 (164.76 days) treatment. Whereas minimum (164.85 days) was found in control. The no or lower application of K fertilizers increased the percentage of size rejects as compared to the plots that received higher levels of K (120 kg K ha^{-1}).

Total soluble solids and allyl- propyl disulphide content were significantly influenced by different sulphur levels. But shelf life was found non- significantly due to sulphur levels. The maximum quality parameters *viz*. TSS, allyl-propyl disulphide content and shelf life of onion bulb at ambient a room temperature (10.44^{o}B, 7.78mg g^{-1} and 166.4 days) was recorded with 40 S kg ha^{-1} (soil application) Whereas, minimum was registered under control (S_1) Similarly, TSS and allyl propyl disulphide content in bulb increased with increasing level of sulphur (Table 4). The increased sulphur and allyl propyl disulphide content in bulb might be due to increased concentration of sulphur in soil with increasing level of sulphur fertilization.

Quality changes of the dried product were evaluated by analysis of colour, pyruvate, chemical and sensory parameters. The obtained results are in conformity with (Nasreen *et al.*, 2007 and Shaheen *et al.*, 2011) [47, 55]. The better root growth, particularly development of lateral roots and fibrous rootlets which is responsible for higher nutrients uptake from the soil that is positively encouraged by nitrogen (Barker, 2007) [11] on the bulb size of onion as affected by mineral nutrients (Pandey *et al.*, 1991) [48]. Nitrogen help in vigorous vegetative growth and imparted deep green colour to the foliage which favored photosynthetic activity of the plants so there was greater accumulation of food *i.e.* carbohydrates in bulb which synthesized to saccharides and there was increase in TSS content also been reported by (Singh *et al.*, 1989 and Thabet *et al.*, 1994) [56, 57]. Similar sulphur levels findings have also been reported by better quality, higher nutrient uptake and sustainable nutrient bulb up in the soil (Dudhat *et al.*, 2011) [27]. Similarly, TSS and allyl propyl disulphide content in bulb increased with increasing level of sulphur. The increased sulphur and allyl propyl disulphide content in bulb might be due to increased concentration of sulphur in soil with increasing level of sulphur fertilization. Similar results were also found by Mishu *et al.* (2013) [45] in onion. Application of graded levels of S from 0 to 45 kg S/ha significantly influenced the seed yield, of nitrogen and sulphur, protein content in seed of mung bean (Dharwe *et al.*, 2019) [17]. Rathore (1985) [53] concluded that nutrient content and uptake of nutrients increased significantly with increase in S level up to 80 kg ha^{-1}in groundnut. That S application (45 kg ha^{-1}) recorded an uptake of 94.44, 23.89, 78.65 and 32.54 kg ha^{-1} for N, P, K and sulphur were found significantly superior the values recorded with rest of the levels (Bekele *et al.*, 2018 and Chattoo *et al.*, 2012) [12, 14]. Studied that the better quality, higher nutrient uptake and sustainable nutrient bulb up in the soil (Dudhat *et al.*, 2011). These results are also in accordance with the findings of (Mahla, 2015 and Bairwa *et al.*, 2017) [40, 9].

Table 1: Effect of nitrogen, potassium and sulphur on Number of leaves per plant onion

Treatments	Number of leaves per plant								
	30 DAT			60 DAT			90 DAT		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Nitrogen levels									
N_1	3.41	4.06	3.73	4.24	4.88	4.56	5.27	5.96	5.62
N_2	4.56	5.20	4.88	5.95	6.57	6.26	6.58	7.72	7.15
N_3	4.82	5.47	5.14	6.15	6.84	6.49	6.88	8.04	7.46
N_4	4.52	5.16	4.84	5.92	6.54	6.23	6.47	7.62	7.04
SEM±	0.04	0.05	0.03	0.05	0.07	0.05	0.091	0.047	0.051
CD at 5%	0.13	0.16	0.09	0.19	0.25	0.14	0.316	0.161	0.158
Potassium levels									
K_1	3.72	4.38	4.05	4.98	5.66	5.32	5.60	6.66	6.13
K_2	4.52	5.16	4.84	5.73	6.36	6.04	6.51	7.58	7.04
K_3	4.56	5.20	4.88	5.85	6.48	6.16	6.59	7.66	7.12
K_4	4.51	5.15	4.83	5.71	6.33	6.02	6.50	7.45	6.97
SEM±	0.03	0.04	0.03	0.05	0.05	0.03	0.07	0.04	0.04
CD at 5%	0.10	0.11	0.07	0.13	0.13	0.09	0.19	0.12	0.11

Sulphur levels									
S_1	3.91	4.56	4.24	5.06	5.66	5.36	5.90	6.86	6.38
S_2	4.74	5.39	5.06	6.06	6.76	6.41	6.70	7.82	7.26
SEM±	0.02	0.03	0.02	0.03	0.03	0.02	0.05	0.03	0.03
CD at 5%	0.07	0.08	0.05	0.10	0.09	0.06	0.13	0.09	0.08

Table 2: Response of Nitrogen, Potassium and Sulphur on Physiological Growth and Yield of onion

Treatments	Plant height (cm)									Bulb Yield (q ha^{-1})		
	30 DAT			60 DAT			90 DAT					
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Nitrogen levels												
N_1	15.19	16.82	16.01	30.07	31.44	30.76	38.35	40.02	39.18	135.38	138.78	137.08
N_2	17.86	19.06	18.46	35.14	37.04	36.09	44.31	46.66	45.48	209.21	211.70	210.45
N_3	18.63	19.84	19.24	36.18	37.84	37.01	46.16	48.40	47.28	224.77	230.48	227.62
N_4	17.80	19.00	18.40	34.92	36.82	35.87	44.29	46.50	45.39	205.26	207.78	206.52
SEM±	0.21	0.20	0.14	0.30	0.42	0.26	0.49	0.53	0.36	2.44	2.61	1.79
CD at 5%	0.72	0.69	0.45	1.02	1.45	0.79	1.68	1.85	1.11	8.46	9.03	5.51
Potassium levels												
K_1	16.34	17.78	17.06	32.02	33.78	32.90	40.63	42.64	41.63	149.80	153.14	151.47
K_2	17.58	18.96	18.27	34.55	36.37	35.46	43.94	45.99	44.97	206.20	209.87	208.04
K_3	18.24	19.57	18.91	35.30	36.77	36.03	44.90	47.13	46.01	216.29	220.12	218.21
K_4	17.32	18.41	17.87	34.44	36.23	35.33	43.63	45.82	44.72	202.32	205.60	203.96
SEM±	0.13	0.14	0.10	0.23	0.25	0.17	0.34	0.35	0.25	2.24	2.28	1.60
CD at 5%	0.38	0.41	0.27	0.65	0.70	0.47	0.97	1.00	0.69	6.35	6.47	4.48
Sulphur levels												
S_1	16.81	18.04	17.43	33.21	34.80	34.00	42.46	44.44	43.45	180.47	183.98	182.23
S_2	17.94	19.32	18.63	34.94	36.77	35.86	44.09	46.35	45.22	206.84	210.38	208.61
SEM±	0.09	0.10	0.07	0.16	0.17	0.12	0.24	0.25	0.17	1.58	1.62	1.13
CD at 5%	0.27	0.29	0.19	0.46	0.49	0.33	0.69	0.71	0.49	4.49	4.58	3.17

Table 3: Effect of nitrogen, potassium and sulphur on weight of onion leaves per plant (g) at 90 DAT

Treatments	Fresh weight of leaves			Dry weight of leaves		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Nitrogen levels						
N_1	8.66	8.92	8.79	1.75	2.58	2.17
N_2	12.38	13.36	12.87	2.75	3.20	2.98
N_3	12.83	13.84	13.34	2.94	3.30	3.12
N_4	12.23	13.23	12.73	2.70	3.10	2.90
SEM±	0.15	0.16	0.11	0.03	0.03	0.02
CD at 5%	0.53	0.57	0.34	0.12	0.11	0.07
Potassium levels						
K_1	9.90	10.83	10.36	2.12	2.80	2.46
K_2	11.98	12.65	12.31	2.65	3.11	2.88
K_3	12.31	13.24	12.77	2.78	3.23	3.00
K_4	11.92	12.64	12.28	2.60	3.05	2.82
SEM±	0.14	0.19	0.12	0.03	0.02	0.02
CD at 5%	0.40	0.55	0.34	0.09	0.05	0.05
Sulphur levels						
S_1	11.40	12.23	11.82	2.49	3.02	2.76
S_2	11.65	12.45	12.05	2.58	3.07	2.83
SEM±	0.10	0.14	0.09	0.02	0.01	0.01
CD at 5%	NS	NS	NS	0.06	0.04	0.04

Table 4: Effect of nitrogen, potassium and sulphur on Quality parameters of onion

Treatments	Total soluble solids (^{0}B)			Allyl-propyl disulphide (mg g^{-1})			Shelf life at ambient room temperature (days)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Nitrogen levels									
N_1	9.37	10.09	9.73	6.96	7.09	7.02	167.76	167.65	167.70
N_2	10.09	10.45	10.27	7.20	7.24	7.22	161.94	166.18	164.06
N_3	10.46	10.68	10.57	7.57	7.60	7.59	163.26	166.21	164.73
N_4	10.04	10.36	10.20	7.15	7.19	7.17	166.52	168.54	167.53
SEM±	0.11	0.10	0.08	0.11	0.09	0.07	1.96	1.79	1.33
CD at 5%	0.38	0.36	0.23	0.36	0.29	0.21	NS	NS	NS
Potassium levels									
K_1	9.79	10.07	9.93	6.94	6.98	6.96	163.70	166.00	164.85

K_2	10.07	10.39	10.23	7.24	7.37	7.31	167.55	169.93	168.74
K_3	10.18	10.77	10.48	7.48	7.45	7.47	164.57	166.79	165.68
K_4	9.93	10.34	10.13	7.23	7.31	7.27	163.67	165.86	164.76
SEM±	0.06	0.08	0.05	0.08	0.08	0.06	1.78	1.67	1.22
CD at 5%	0.18	0.24	0.15	0.24	0.22	0.16	NS	NS	NS
Sulphur levels									
S_1	9.75	10.14	9.94	6.61	6.82	6.72	163.57	168.39	165.98
S_2	10.23	10.65	10.44	7.83	7.74	7.78	166.17	165.90	166.04
SEM±	0.05	0.06	0.04	0.06	0.06	0.04	1.26	1.18	0.86
CD at 5%	0.13	0.17	0.10	0.17	0.16	0.11	NS	NS	NS

Conclusions

The experimental results showed that the main effects of nitrogen, phosphorus, potassium, and sulphur as well as their interactions had considerable influence on different parameters. Application of N, K and S levels recorded the highest bulb yield at N (227.62 q ha^{-1}), K (218.21q ha^{-1}), S (208.61 qha^{-1}), which were closely superior to other treatments during both years on a pooled basis. Under different K applications, the shelf life of onion bulbs at room temperature was insignificant. The shelf life of an onion bulb at ambient room temperature was observed to be 168.74 days for the 100 Kg ha^{-1} (soil application) treatment, which was closely followed by K_3 (165.68 days) but superior to the control. Maximum K application of K_3 registered the highest TSS (10.48 oB) and allyl propyl disilphide (7.47 mg g^{-1}) in onion over control, closely followed by K_2 (10.23 oB and 7.31 mg g^{-1}) but were significantly superior to K_1 and K_4 treatment during both years.

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