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Effect of different levels of irrigation and NPK and S fertigation on NPK and S Content (%) and Uptake (kg ha^{-1}) of onion

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Abstract
The present experiment entitled "Evalution of different levels of NPKS and irrigation for onion for sandy clay loam soils under drip enviroment" was conducted at Instructional farm Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur (Chhattisgarh) during *rabi* season 2022-23. Results indicated that the different irrigation treatments through drip showed significant variation in. NPK and S content and uptake of onion. The irrigation treatment I_1 (80% ETc) found significantly superior over I_2 (60%ETc). Irrigation at 80%ETc (I_1) gave through drip were recorded NPK and S content% of leaf and bulb. highest leaf content was 1.62%, 0.25%, 1.42%, and 1.21% and highest bulb content was 1.96%, 0.48%, 2.28%, 1.93% respectivally recorded by irrigation I_1 (80%ETc) which was superior over I_2 (60% ETc).
Application of different NPK and S fertigation levels showed significant influence on Uptake of leaves and bulb of onion. Maximum leaves uptake 41.14, 7.62, 36.06 and 30.48 kg ha^{-1} and bulb uptake on NPK and S are 56.45, 13.89, 67.10 and 56.75 kg ha^{-1} was obtained by F_3 (50% NPK and 7.5 kg ha^{-1} S as basal + 50% NPK and 7.5 kg S ha^{-1} through fertigation) when compared to superior over F_8, however F_5, F_2, F_4, F_1 respectively were found statistically *at par*. The content and uptake of N, P, K and S in leaves and bulb significantly varied due to different drip irrigation treatments and NPK and S fertigation level.

Keywords: NPKS (Nitrogen, phosphorus, potassium, sulphur, content and uptake leaves and bulb, fertigation, result and conclusion

Introduction
The onion (*Allium cepa* L.) is a herbaceous biennial vegetable and a member of the Amaryillidaceae (Alliaceae) family. The onion growths separate bulb. According to the variety, these bulbs vary in size (slight, medium and large), colour (white, yellow, or red), shape (flattened, round or globular), texture (fine, or coarse and pungency). The crop is grown for feasting eating in green state as well as mature bulbs. Onions are extensively used as condiment in the preparation of curry, chutney and pickle etc.
India ranks first in area, second in production and third in export in the world. Total area of onion in India is 1434 ('000 ha) and production is 26738 ('000 MT). (Anonymous NHB 2019-20).
Onion is one of the most important bulbous crops of the Chhattisgarh and gaining ahead popularity day by day as an important profitable vegetable crop. It is mainly cultivated in Surguja, Balrampur, Bilaspur, Durg, Janjgir-Champa and Raipur districts of the state with a total area of 25542 ha. Production of onion is 418119 MT.
Patgiri and Baruch (1993) revealed that S content in soil improved with increasing S levels up to 80 kg ha^{-1} at all crop growth stages.
Nasreen *et al.* (2007) recorded that the uptake of nutrients were increased with the increasing levels of nitrogen (0, 80,120 and 160 kg ha^{-1}) and sulphur (0, 20, 40 and 60 kg ha^{-1}) fertilization. The highest uptake of nitrogen and sulphur was found at higher levels of nitrogen and sulphur fertilization (160 and 60 kg ha^{-1}, respectively) in onion *var*., Nasik red.

Salo *et al*. (2001) reported that the onion yielded 40-50 t ha^{-1}, with uptake of 117-166 kg N, 18-28 kg P, 117-136 kg K and 20-30 kg sulphur ha^{-1}.

Sundar Raman *et al.* 2000 observed that application of 100 percent NPK in the form of urea and polyfeed recorded the highest nutrient uptake of 184 kg N, 53 kg P and 325 kg K ha^{-1}.

The combined application of 75 kg ha-1 nitrogen and 150 kg ha^{-1} potassium fertilizer gave the highest value of N, P and K content in bulb (5.42, 34.20 and 164.92 mg/100 g, respectively) and leaves (0.24, 21.78 and 142.62 mg/100 g, respectively), while the lowest value of nitrogen, phosphorus and potassium content in bulb (4.31, 26.92 and 150.75 mg/100 g) and leaves (0.20, 17.43 and 124.93 mg/100 g, respectively) was obtained with the combined application of 45 kg/ha nitrogen and 60 kg/ha potassium fertilizer.

The maximum uptake of N, P and K at 60, 90 and at harvest was found with 100% fertigation (38.12, 78.24 and 96.60 kg ha^{-1} N, 18.55, 34.53 and 50.74 kg ha^{-1} P and 23.18, 74.72 and 86.24 kg ha^{-1} K, respectively), however, it was at par with 100% fertigation under micro-sprinkler. The lowest total NPK uptake was recorded when no fertilizer was given under drip irrigation.

Onion yielded 40-50 t ha^{-1}, with uptake of 117-166 kg N, 18-28 kg P and 117-136 kg K ha^{-1}.

Materials and Methods

The experiment was conducted during the year 2022-23 in Instructional farm, Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur (C.G.) during *rabi* season. The experiment was laid out in split plot design with with three replications and eight treatment combination consisted of two levels of drip irrigation (80% and 60% ETc) as main plots and eight levels of NPK and S fertigation as sub plot *viz*. F_1: 100% NPK and 7.5 kg S ha^{-1} through fertigation, F_2: 25% NPK as basal + 75% NPK and 7.5 kg S ha^{-1} through fertigation, F_3: 50% NPK and 7.5 kg S ha^{-1} as basal + 50% NPK and 7.5 kg S ha^{-1} through fertigation, F_4: 100% NPK through fertigation + 10 kg S ha^{-1} through soil application, F_5: 25% NPK as basal + 75% NPK and 10 kg S ha^{-1} through fertigation, F_6: 75% NPK through fertigation + 10 kg S ha^{-1} through soil application, F_7: 75% NPK as basal and 15 kg S ha^{-1} through fertigation, F_8: 19% NPK as basal + 56% NPK and 15 kg S ha^{-1} through fertigation.

Dried leaf and bulb were grinded and used for following chemical analysis. the plant samples were collected at the time of harvest. The samples kept in paper covers were sun dried first and then it was oven dried in a hot air oven at a temperature of 60ºC till a constant weight was recorded. Digestion of plant sample for NPK content, the oven dried plant sample was powdered in grinding mill and then weighedfor 0.5 g leaf and 0.2 g bulb material in 100 ml conical flask. Add 10 ml diacid mixture of H_2SO_4 and $HClO_4$ acid in 9:1 ratio. Keep it for overnight. Keep it on hot plate and heat gently at first. Then heat more vigoursly until a clear colourless solution results or till white fumes cease to come out. Cool it and transfer into 50 ml volumetric flask and then make volume up to mark by adding distilled water. Filter it with whatman No. 1 filter paper and use for further analysis. Digestion procedure for sulphur content in bulb is similar to NPK content in bulb. Take 2.5 ml aliquot in 25 ml volumetric flask and add 1 ml gum acacia solution. Add 1 g sieved barium chloride, make the volume to mark and shake for 1 minute. Then measure the turbidity, 25 to 30 minute after precipitation on spectrophotometer, using a blue filter at a wavelength of 420 nm.

Uptake on leaves and bulb: From the yield of total dry matter and contents of nitrogen, phosphorus and potassium were used to compute the total uptake of respective nutrients and worked out using following formula suggested by Piper 1966 and was expressed in kg ha^{-1}.

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Nutrient content (\%) X total dry matter production ha}^{-1}}{100}$$

Results and Discussion

NPK and S content of leaf and bulb of onion (%)

Nitrogen content (%) in onion leaf and bulb

A keen examination of the data (Table 1) shows the significant influence on nitrogen content% in leaf due to the various drip irrigation levels. Maximum nitrogen content of leaf and bulb was 1.62% and 1.99% observed in the irrigation levels I_1 (80%ETc). However, irrigation levels I_2 (60%ETc) were found *at par*.

Whereas, among the NPK and sulphur fertigation levels the highest nitrogen content 1.62% and 1.90% respectivally was found with F_3 (50% NPK and 7.5 kg ha^{-1} S as basal + 50% NPK and 7.5 kg S ha^{-1} through fertigation). Where F_3 (50% NPK and 7.5 kg ha^{-1} S as basal + 50% NPK and 7.5 kg S ha^{-1} through fertigation) and F_2 and F_5 were found *at par* with each other. Least nitrogen content was observed 1.57% and 1.90% with F_6 (75% NPK through fertigation + 15 kg S ha^{-1} through soil application).

The increased N content (%) due to sulphur application has also been reported by Sharma *et al*. (1990) [9], Lekh Chand *et al*. (1996) and Chauhan (1998) [10].

Phosphorus content (%) of onion leaf and bulb

Perusal of the data (Table 1) shows that the different levels of drip irrigation and NPK and sulphur fertigation levels significantly influenced the phosphorus content% in leaf of the onion. Irrigation levels I_1 (80%ETc) was found 0.25% and 0.48% superior among the drip irrigation levels I_2 (60% ETc) was phosphorus content 0.23% and 0.45%.

Whereas, among NPK and sulphur levels highest phosphorus content (0.30% and 0.47%) in leaf was recorded with treatment F_3 (50% NPK and 7.5 kg ha^{-1} S as basal + 50% NPK and 7.5 kg S ha^{-1} through fertigation. followed by treatment F_5, where 25% NPK of RDF were applied as basal but both the treatments found significantly superior over F_8, however F_5 and F_2 were found statistically *at par*. The lowest content of onion leaf 0.15% 0.32% *i.e.*, were recorded under treatment F_6 (75% NPK through fertigation + 15 kg S ha^{-1} through soil application) at harvest.

Similar data also reported by Jat and Mehra (2007) stated that the application of nitrogen sulphur significantly increased the phosphorus.

Potassium Content (%) of leaf and bulb

Drip irrigation and NPK and sulphur fertigation levels significantly influenced the potassium content% in leaf and bulb of the onion. A keen examination of the data (Table 1) shows that the drip irrigation levels I_1 (80%ETc) was observed (1.42% and 2.28%) as compared to rest of irrigation levels,while the minimum potassium content in leaf and bulb (1.39%, 2.16% respectively) was recorded with drip irrigation at 60%ETc in treatments.

Whereas, among the NPK and sulphur levels the maximum potassium content (1.41% and 2.28%) in leaf and bulb was found in F_3 (50% NPK and 7.5 kg ha^{-1} S as basal + 50% NPK and 7.5 kg ha^{-1} S through fertigation). Whereas F_3 (50% NPK

and 7.5 kg ha^{-1} S as basal + 50% NPK and 7.5 kg ha^{-1} S through fertigation), F_2 (25% NPK as basal + 75% NPK and 7.5 kg S ha^{-1} through fertigation) and F_7(75% NPK and 15 kg S ha^{-1} through fertigation) were *at par* with each other. The lowest content of onion leaf and bulb of potassium 1.025% and 1.89% were recorded under treatment F_6 (75% NPK through fertigation + 15 kg S ha^{-1} through soil application) at harvest stages.

Sulphur Content (%) of leaf and bulb of onion

The sulphur content% in leaf of onion significantly influenced by the different levels of drip irrigation and NPK and sulphur fertigation. The keen investigation the data (Table 1) depicted that the drip irrigation levels I_1 (80%ETc) was found (1.21% and 1.93%). The least sulphur content (1.15% and 1.86%) in leaf and bulb was found with drip irrigation levels I_2 (60% ETc) in treatment.

Whereas, among the NPK and sulphur fertigation levels the maximum sulphur content in leaf and bulb was found (1.20% and 1.93%) in F_3 (50% NPK and 7.5 kg ha^{-1} S as basal + 50% NPK and 7.5 kg S ha^{-1} through fertigation). F_3, F_1, F_2, F_4, F_5, F_7, F_8 were found with *at par*. Minimum sulphur content (1.13% and 1.50%) in leaf and bulb was found with in treatment F_6 (75% RDF + 10 kg S). Interaction effect on Sulphur content in leaf between drip irrigation and NPK and sulphur fertigation levels options was found non-significant.

The results of present investigation corroborate with the findings of Patel (1992), Jain *et al.* (1995) and Chauhan (1998) [10].

Table 1: NPK and S content of leaf and bulb of onion (%)

Treatments	N Content (%) of leaf	N content (%) of bulb	P Content (%) of leaf	P content (%) of bulb	K Content (%) of leaf	K content (%) of bulb	S Content (%) of leaf	S Content (%) of bulb
Factor A - Drip irrigation								
I_1 - (80% ETc)	1.62	1.96	0.25	0.48	1.42	2.28	1.21	1.93
I_2 - (60% ETc)	1.61	1.91	0.23	0.45	1.39	2.16	1.15	1.86
SE(m) ±	1.0158	0.025	0.20	0.015	1.14	0.06	0.97	0.035
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Factor B – N, P, K and S Fertigation								
F_1 -100% NPK and 7.5 kg S ha^{-1} through fertigation	1.59	1.92	0.21	0.44	1.16	2.06	1.19	1.88
F_2 -25% NPK as basal + 75% NPK and 7.5 kg S ha^{-1} through fertigation	1.61	1.91	0.25	0.47	1.41	2.27	1.19	1.92
F_3 -50% NPK and 7.5 kg ha^{-1} S as basal + 50% NPK and 7.5 kg S ha^{-1} through fertigation	1.62	1.99	0.30	0.47	1.42	2.28	1.20	1.93
F_4 -100% NPK through fertigation + 10 kg S ha^{-1} through soil application	1.59	1.91	0.19	0.42	1.19	2.07	1.20	1.81
F_5 -25% NPK as basal + 75% NPK and 10 kg S ha^{-1} through fertigation	1.59	1.92	0.29	0.46	1.41	2.23	1.18	1.91
F_6 -75% NPK through fertigation + 15 kg S ha^{-1} through soil application	1.57	1.90	0.15	0.34	1.02	1.89	1.13	1.50
F_7 -75% NPK and 15 kg S ha^{-1} through fertigation	1.61	1.94	0.28	0.32	1.40	2.26	1.20	1.90
F_8 -19% NPK as basal + 56% NPK and 15kg S ha^{-1} through fertigation	1.60	1.93	0.23	0.42	1.39	2.03	1.18	1.55
SE(m) ±	0.01	0.36	0.01	0.095	0.017	0.071	0.017	0.052
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Nitrogen uptake (kg ha^{-1}) of onion leaf and bulb

The data showed (Table 2) that the uptake of nitrogen kg ha^{-1} in leaf and bulb was affected significantly due to effect of drip irrigation and NPK and sulphur fertigation levels. Irrigation level I_1 (80% ETc) was recorded the highest N uptake 36.45 kg ha^{-1} and 44.17 kg ha^{-1} respectivally. Minimum N uptake in leaf and bulb was observed 30.75 kg ha^{-1} and 36.65 kg ha^{-1} in the irrigation levels I_2 (60% ETc).

The significantly maximum Nitrogen of onion leaf and bulb was 41.14 and 56.45 kg ha^{-1} individually recorded under treatment F_3 (50% NPK and 7.5 kg ha^{-1} S as basal + 50% NPK and 7.5 kg ha^{-1} S through fertigation) followed by treatment F_5, found significantly superior over F_8, however F_5 and F_2 were found statistically *at par*. Similar way treatments F_4, F_1, and F_7 were showed non-significant. The lowest leaf and bulb uptake of nitrogen 28.57 and 38.15 (kg ha^{-1}), were recorded under treatment F_6 (75% NPK through fertigation + 15 kg S ha^{-1} through soil application).

Phosphorus uptake (kg ha^{-1}) of onion leaf and bulb

The specific effects of drip irrigation and NPK and sulphur fertigation levels had a significantly impact on the effect of on phosphorus absorption in leaf and the date are presented in table 2. The highest P uptake leaf and bulb was (5.67 and 10.81 kg ha^{-1}) was observed with irrigation level I_1 (80% ETc). However, irrigation level I_2 (60% PE) were *at par* with each other 4.39 and 8.63 kg ha^{-1} was noticed that

Among the NPK and S fertigation level F_3 (50% NPK and 7.5 kg ha-1 S as basal + 50% NPK and 7.5 kg ha-1 S through fertigation) had the highest P uptake (7.62 and 13.89 kg ha^{-1}), followed by treatment F_5, where both the treatments found significantly superior over F_8, however F_5 and F_2 were found statistically *at par*. The least uptake of P (2.43 and 6.47 kg ha^{-1}) was noticed with F_6 (75% NPK through fertigation + 15 kg S ha^{-1} through soil application).

Potassium uptake (kg ha^{-1}) of onion leaf and bulb

The data showed (Table 2.) that the effect of potassium uptake (kg ha^{-1}) in leaf and bulb was stongly influenced by the levels of drip irrigation and NPK and S fertigation. Irrigation level I_1 (80%ETc) was recorded the highest K uptake (36.23 and 55.30 kg ha^{-1}). However, Irrigation levels I_2 (60% PE) 26.54 and 41.45 (kg ha^{-1}) was found lowest uptake in potassium leaf and bulb.

Similar to this, among the NPK and S levels, F_3 (50% NPK and 7.5 kg ha^{-1} S as basal + 50% NPK and 7.5 kg ha^{-1} S through fertigation) had the highest (36.06 and 67.10 kg ha^{-1}) K uptake in leaf and bulb. Whereas followed by treatment F_5, superior over F_8, however F_5 and F_2 were found statistically *at par*. The minimum K uptake (kg ha^{-1}) in leaf and bulb was recorded F_6 (75% NPK through fertigation + 15 kg S ha^{-1} through soil application) 18.56 and 37.95 kg ha^{-1}.

Sulphur uptake (kg ha^{-1}) of onion leaf and bulb

The data presented in (Table 2) revealed that the effect of NPK and sulphur in leaf (kg ha^{-1}) was affected significantly due to the levels of drip irrigation and NPK ans S fertigation. Treatment I_1 (80% ETc) was found superior among the drip irrigation levels. The maximum and minimum S uptake leaf and bulb were found in irrigation levels I_1 80% ETc (29.46 and 46.21 kg ha^{-1}) and I_2 60% ETc (21.96 kg ha^{-1}). The minimum S uptake (35.69 kg ha^{-1}) by bulb was recorded.

The significantly maximum sulphur uptake of onion leaf and bulb (kg ha^{-1}) 30.48 and 56.75 recorded under treatment F_3 (50% NPK and 7.5 kg ha^{-1} S as basal + 50% NPK and 7.5 kg ha^{-1} S through fertigation) followed by treatment F_5 found significantly superior over F_8, however F_5 and F_2 were found statistically *at par*. The lowest leaf and bulb uptake of sulphur 20.56 and 30.12 (kg ha^{-1}), were recorded under treatment F_6 (75% NPK through fertigation + 15 kg S ha^{-1} through soil application).

Table 2: Effect of different level of irrigation and NPK & S fertigation on nitrogen, phosphorus, potassium and sulphur uptake (kg ha^{-1}) of leaf and bulb of onion

Treatments	N uptake kg ha^{-1} of leaf	N uptake kg ha^{-1} of bulb	P uptake kg ha^{-1} of leaf	P uptake kg ha^{-1} of bulb	K uptake kg ha^{-1} of leaf	K uptake kg ha^{-1} of bulb	S uptake kg ha^{-1} of leaf	S uptake kg ha^{-1} of bulb
Factor A - Drip irrigation								
I_1 - (80% ETc)	36.77	44.17	5.67	10.81	32.23	51.30	29.46	46.21
I_2 - (60% ETc)	30.75	36.65	4.39	8.63	26.54	41.45	21.96	35.69
SE(m) ±	2.85	2.76	0.60	1.08	2.84	4.92	2.58	3.90
CD (0.05)	5.64	8.87	0.85	1.53	8.52	12.56	6.64	9.52
Factor B – N, P, K and S Fertigation								
F_1 -100% NPK and 7.5 kg S ha^{-1} through fertigation	34.66	46.84	4.57	10.73	25.28	50.26	25.94	45.87
F_2 -25% NPK as basal + 75% NPK and 7.5 kg S ha^{-1} through fertigation	36.22	50.12	5.62	11.83	31.72	57.43	26.77	48.61
F_3 -50% NPK and 7.5 kg ha^{-1} S as basal + 50% NPK and 7.5 kg S ha^{-1} through fertigation	41.14	56.45	7.62	13.89	36.06	67.10	30.48	56.75
F_4 -100% NPK through fertigation + 10 kg S ha^{-1} through soil application	34.50	43.18	4.12	9.44	25.82	46.55	26.04	40.70
F_5 -25% NPK as basal + 75% NPK and 10 kg S ha^{-1} through fertigation	35.29	46.27	6.43	11.08	31.30	53.74	26.19	46.03
F_6 -75% NPK through fertigation + 15 kg S ha^{-1} through soil application	28.57	38.15	2.43	6.82	18.56	37.95	20.56	30.12
F_7 -75% NPK and 15 kg S ha^{-1} through fertigation	30.42	39.24	5.29	6.47	26.46	45.71	22.68	38.43
F_8 -19% NPK as basal + 56% NPK and 15 kg S ha^{-1} through fertigation	33.44	39.98	4.80	8.70	29.05	42.06	24.66	32.11
SE(m) ±	1.89	2.35	0.57	0.89	2.28	3.27	1.41	3.11
CD (0.05)	4.35	6.22	1.61	2.52	6.45	9.25	4.10	8.82

Suggestions for future research work

- By increasing the efficiency factors, it is necessary to test the fertilizer prescription formulations developed for onion crop under different soil conditions for several agro-climatic zones.
- Validation and improvement should be done continuously to see improvement over time.
- Additional research was sought to investigate the effects of various NPK and sulphur fertigation levels on onion under long-term fertilizer test.
- Additional research should be done to better understand the NPK and sulphur fractions and how it interacts with the physico-chemical properties of the soil.

Conclusion

The experiment titled "Evaluation of Different Levels of NPKS and Irrigation for Onion in Sandy Clay Loam Soils under Drip Environment" conducted at Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur, during the rabi season of 2022-23, provides valuable insights into optimizing nutrient management and irrigation for onion cultivation.

Key Findings

1. **Irrigation Levels:** Drip irrigation at 80% ETc (I1) proved to be significantly more effective than irrigation at 60% ETc (I2) in enhancing the nutrient content and uptake in both leaves and bulbs of onions. Specifically, I1 resulted in higher nitrogen (1.62% in leaves, 1.96% in bulbs), phosphorus (0.25% in leaves, 0.48% in bulbs), potassium (1.42% in leaves, 2.28% in bulbs), and sulphur content (1.21% in leaves, 1.93% in bulbs). The increased nutrient availability due to I1 also led to higher nutrient uptake in both leaves and bulbs.
2. **NPK and S Fertigation Levels:** Among the different fertigation treatments, F3 (50% NPK and 7.5 kg ha^-1 S as basal + 50% NPK and 7.5 kg ha^-1 S through fertigation) consistently showed superior results. It yielded the highest content and uptake of nitrogen, phosphorus, potassium, and sulphur in both onion leaves and bulbs. Specifically, F_3 resulted in the highest nitrogen uptake (41.14 kg ha^-1 in leaves, 56.45 kg ha^-1 in bulbs), phosphorus uptake (7.62 kg ha^-1 in leaves, 13.89 kg ha^-1 in bulbs), potassium uptake (36.06 kg ha^-1 in leaves, 67.10 kg ha^-1 in bulbs), and sulphur uptake (30.48 kg ha^-1 in leaves, 56.75 kg ha^-1 in bulbs).
3. **Other Fertigation Treatments:** Treatments such as F_5 and F_2 also performed well, showing comparable results to F_3 in several nutrient metrics. In contrast, F_6 (75% NPK through fertigation + 15 kg S ha^-1 through soil application) had the lowest nutrient content and uptake, indicating less efficacy in meeting the plant's nutritional needs.

Implications

The results underscore the importance of using 80% ETc for drip irrigation and a balanced fertigation approach, particularly F3, to optimize nutrient content and uptake in onions. This practice not only enhances the nutritional quality of onions but also improves overall yield and productivity.

Suggestions for Future Research

1. **Fertilizer Prescription Validation:** Test and validate fertilizer prescription formulations under varied soil conditions and agro-climatic zones to refine recommendations for onion cultivation.
2. **Efficiency Improvements:** Continuously evaluate and improve fertilizer application techniques to enhance nutrient efficiency and crop performance over time.
3. **Extended Research:** Investigate the long-term effects of different NPK and sulphur fertigation levels on onion yield and quality to establish best practices for sustained productivity.

Overall, the findings offer practical insights for optimizing irrigation and fertigation practices in onion cultivation, which can be adapted for better resource use efficiency and crop productivity.

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