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Nutrient management in white onion (*Allium cepa*) and its effect on growth and yield

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Abstract
A field experiment was carried out during *rabi* season of 2021-2022 and 2022-2023 at Instructional Farm, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, College of Agriculture, Dapoli, Dist. Ratnagiri, Maharashtra, to study the nutrient management in white onion (*Allium cepa*) and its effect on growth and yield. The experiment was laid out in split plot design with twenty treatment combinations replicated thrice. The main plot consisted of four conventional fertilizer treatments: F_1 - control, F_2 - 100% RD of N and P + 100% RD of K, F_3-75% RD of N and P + 100% RD of K and F_4 - 50% RD of N and P + 100% RD of K, the sub-plot consisted of five nano-fertilizer treatments: N_1 - control, N_2 - 25% RD of N through Nano-urea + 25% RD of P through Nano-phosphorous, N_3 - 50% RD of N through Nano-urea + 25% RD of P through Nano-phosphorous, N_4 - 25% RD of N through of Nano-urea + 50% RD of P through Nano-phosphorous and N_5 - 50% RD of N through of Nano-urea + 50% RD of P through Nano-phosphorous. It was found that, the conventional fertilizer treatment F_2 (100% RD of N and P + 100% RD of K) and the nano fertilizer treatment N_3 (50% RD of N through nano-urea + 25% RD of P through nano-phosphorous) recorded significantly higher growth and yield in white onion. Further, the treatment combination F_2N_3 [100% RD of N and P + 100% RD of K and 50% RD of N through nano-urea + 25% RD of P through nano-phosphorous (2 sprays at 45 and 60 DAT)] recorded significantly higher number of functional leaves plant^{-1}, bulb neck diameter, bulb fresh weight bulb^{-1} (g) and bulb yield (q ha^{-1}) in white onion.

Keywords: White onion, conventional fertilizers, nano-fertilizers, growth, yield attribute and yield

Introduction
The onion (*Allium cepa*), is a well-known spice that is grown and consumed in a variety of ways worldwide. It is a member of the *Amaryllidaceae* or *Alliaceae* family. According to McCullum (1976), the primary origin of onions is in Central Asia, with the near East serving as a secondary center. It stretches from Palestine to India, taking up a sizable portion of Western Asia. Central Asia is the primary origin of garlic, with the Mediterranean region serving as a secondary origin (McCollum, 1976) [9]. Globally 1,30,721 metric tonnes of onions were produced during 2021, with the United States of America, China, India, Egypt, and Turkey being the top five onion-producing nations (Anonymous, 2021) [2]. India produced 31.27 million tonnes of onions under 1.91 million hectares of land in 2021–2022, (Anonymous, 2022) [3]. In India, there are three distinct crop seasons for growing onions: *kharif*, late-*kharif*, and *rabi*. 50% of the production comes from the main crop in *rabi* season, while the remaining 20% comes from *kharif* and the remaining 30% from late-*kharif*. The principal states that grow onions are Maharashtra, Karnataka, Gujarat, Bihar, Madhya Pradesh, Rajasthan, Andhra Pradesh, and Tamil Nadu. Maharashtra exports onions to almost 90% of the world. Stored onions are used for both local and international markets from May to November. The market has *kharif* onions from November to December, while late *kharif* crop from Maharashtra is accessible from January to March. However, there is a severe scarcity of onions arriving in the market from November to January.

White onions are grown in the districts of Raigad, Palghar, Nashik, and Ahmednagar in Maharashtra. Only the Alibagh tahsil in the Raigad district of Maharashtra grows white onions in the Konkan region of the state.

The Alibagh white onion has gained international renown for its distinct sweet flavour, ability to cause no tears, and therapeutic qualities after being granted Geographical Indication. Products with value addition and processing are becoming more and more important in global marketplaces. The three main forms of onions that are exported are pickles, canned onions, and dehydrated onions. India ranks second globally in terms of production of dehydrated onions. An easy way to add the flavour of fresh onions is with onion powder, which is a processed version of dehydrated onion. Many food and non-food items, including snacks, sauces, salads, soups, gravies, appetizers, shellfish, meats, etc., today employ onion powder as a flavouring agent.

As significant components of the Mediterranean diet, onions are a good source of various phytonutrients, including thiosulfinates, fructooligosaccharides (FOS), and flavonoids (Slimestad *et al*., 2007) [15]. High concentrations of phenolic compounds found in onions have been shown to have antioxidant qualities in addition to being effective against a variety of degenerative pathologies, such as neurological and cardiovascular disorders, and dysfunctions resulting from oxidative stress (Griffiths *et al*., 2002) [7]. Onions can be utilized as natural preservatives to limit microbial development since sulfur compounds, which give onions their characteristic flavour and odour, are also potent antibacterial agents (Rose *et al*., 2005) [13].

Fertilizers have become essential for increasing crop output and nutritional quality, particularly since crop types that are responsive to fertilizer have been developed. Since nitrogen (N) is a component of many proteins and enzymes as well as chlorophyll, it is the most important mineral nutrient needed by crop plants and is crucial for their vegetative growth. There are several methods that cause nitrogen to be lost to the atmosphere, including runoff, leaching, denitrification, and volatization. All life depends on phosphorus (P), which is also crucial for maintaining and enhancing the fertility of the natural soil. The growing interest in enhancing P use efficiency is being driven by the financial difficulties brought on by rising P fertilizer prices. Moreover, a primary factor contributing to P-induced eutrophication in surface waters is the movement of soil P from farmed land via erosion or runoff. It is somewhat regrettable that contemporary profit-driven agricultural systems only employ 45–50% of nitrogenous fertilizers, whilst reports suggest that only 10–25% of phosphorous fertilizers are used (Iqbal, 2020) [8].

Research in nanotechnology is a promising area that could provide long-term solutions to urgent problems facing contemporary intensive agriculture. In order to achieve controlled and gradual release of nutrients for the development of soil fertility, productivity, and the quality of agricultural products, nano-fertilizers are made from conventional fertilizers, bulk fertilizer materials, or extracted from various plants or plant parts by encapsulating/coating them with nano materials (Zulfiqar *et al*., 2019) [18]. Correct application of nano-fertilizers can feed plants gradually in a way that reduces overall environmental risks, decreases volatilization, stops leaching, and boosts nutrient use efficiency (NUE) (Chen *et al*., 2018) [4].

Materials and Methodology

The experiment was carried out in the *rabi* season of 2021-2022 and 2022-2023. From a geographical standpoint, the experimental plot (B-42) of the instructional farm of the Department of Agronomy, College of Agriculture, Dapoli, is located in the subtropical zone at 17°45'57" N and 73°10'29" E. Slightly above mean sea level, at an elevation of 157.8 meters.

The experiment was conducted using a split plot design. There were three replications and twenty treatment combinations in total. Four traditional fertilizer treatments made up the main plot: F_1 - control, F_2 - 100% RD of N and P + 100% RD of K, F_3 - 75% RD of N and P + 100% RD of K and F_4 - 50% RD of N and P + 100% RD of K; while the sub-plot consisted of five nano-fertilizer treatments *viz.*, N_1 - control, N_2 - 25% RD of N through Nano-urea + 25% RD of P through Nano-phosphorous, N_3 - 50% RD of N through Nano-urea + 25% RD of P through Nano-phosphorous, N_4 - 25% RD of N through of Nano-urea + 50% RD of P through Nano-phosphorous and N_5 - 50% RD of N through of Nano-urea + 50% RD of P through Nano-phosphorous. The gross plot size was 3.60 m × 3.60 m and the net plot size was 3.00 m × 3.40 m. The onion seedlings were transplanted at spacing of 30 cm × 10 cm.

Urea, single super phosphate (SSP), and muriate of potash (MOP) fertilizers were used to apply the nutrients N, P_2O_5 and K_2O, respectively. The recommended dose of conventional fertilizers applied was 100:50:50 NPK kg ha^{-1}. During the transplanting process, the entire dose of SSP and MOP as well as half of the basal dose of urea was applied. Two divided doses of the remaining half-dose of urea were administered at intervals of thirty and sixty days. IFFCO nano urea was used as a source of nano nitrogen which consists of 4.0% total nitrogen (w/v), while nano 17:44:00 formulation of Geolife Agritech India Private Limited was used as a source of nano phosphorous. Both the nano urea and nano phosphorous were sprayed 45 and 60 days after transplanting of white onion.

Results and Discussions

1. Effect of conventional fertilizers

The data presented in the Table 1 shows that, the number of functional leaves plant^{-1} and bulb neck diameter (cm) were influenced significantly due to conventional fertilizer treatments during both the years and in the pooled mean. The treatments F_2 (100% RD of N and P + 100% RD of K) and F_3 (75% RD of N and P + 100% RD of K) were statistically at par with each other and they were significantly superior over rest of the treatments *viz.*, F_4 (50% RD of N and P + 100% RD of K) and F_1 (control) during 2021-2022 and 2022-2023 and in the pooled mean.

As per the data presented in the Table 2, the treatment F_2 (100% RD of N and P + 100% RD of K) recorded significantly higher bulb fresh weight bulb^{-1} (g) during 2021-2022 and in the pooled data, while during 2022-2023 the treatments F_2 (100% RD of N and P + 100% RD of K) and F_3 (75% RD of N and P + 100% RD of K) were at par and both of them recorded significantly higher bulb fresh weight bulb^{-1} over the remaining conventional fertilizer treatments. In terms of bulb yield (q ha^{-1}), during 2021-2022, 2022-2023 and in the pooled data the treatments F_2 (100% RD of N and P + 100% RD of K) and F_3 (75% RD of N and P + 100% RD of K) were statistically similar and both of them recorded significantly higher yield over the remaining treatments.

This results are due to the fact that, the higher supply of major nutrients i.e. nitrogen, phosphorous and potassium under the treatments F_2 and F_3 resulted into the plants under this treatments becoming physiologically more active. Better growth in terms of number of functional leaves plant^{-1} and bulb neck diameter may have been the consequence of the treatments F_2 and F_3 producing more photosynthates due to the increased nutrient availability. Therefore, it can be noted that the treatments F_2 and F_3 had created more source than that of the other conventional fertilizer treatments. Similar findings have been reported by El-Desuki *et al*. (2006) [5], Rizk *et al*. (2012) [12], Simon *et al*.

(2014) [14], and Fekry (2017) [6], who have indicated that, nitrogen is crucial for the synthesis of proteins, enzymes, and chlorophyll, all of which aid in improving the metabolic processes of plants. Further aiding in the acceleration of plant growth is nitrogen's critical involvement in cell division and expansion. Phosphorus is essential for the growth of phospholipids, phosphoproteins, co-enzyme activities, nucleic acid, energy molecules, and roots in plants. It also plays a critical role in the formation of meristematic tissues. Additionally, potassium is clearly involved in the transport of carbohydrates in plants as well as a number of enzymatic processes. The increased production of source under F_2 and F_3 led to relatively higher sink in the form of fresh weight bulb^{-1}, ultimately resulting in significantly higher bulb yield under F_2 and F_3 treatments. These results are similar to those of Yaso and Abdel Razzak (2007) [17], Mohammed *et al.* (2018) [10] and Fekry (2017) [6] who reported that, the supply of nitrogen, phosphorus and potassium fertilizers enhanced growth parameters, which in turn improved onion yield attributes and overall yield. Significantly lower values of the above given growth and yield attributes were recorded by F_1 (control) during both the years and in the pooled mean.

2. Effect of nano fertilizers

Among the nano fertilizer treatments, N_3 [50% RD of N through nano-urea + 25% RD of P through nano-phosphorous (2 sprays at 45 and 60 DAT)] recorded significantly higher values of growth parameters i.e., number of functional leaves plant^{-1} and bulb neck diameter as well as yield parameter i.e. bulb fresh weight bulb^{-1} (g) and bulb yield (q ha^{-1}) during both the years and in the pooled mean (Table 1 and Table 2).

The nano size of the fertilizers and their large effective surface area enables them to get rapidly absorbed by the plants through stomatal and pore openings and also to participate in various biochemical and physiological processes within plants. Upadhyay *et al.* (2023) [16] reported that, the efficiency of conventional fertilizers is 30-35%, whereas that of nano fertilizers is about 80%. Therefore, the doses of 50% nitrogen through nano urea and 25% phosphorus through nano phosphorus were sufficient for the crop because of the higher nutrient efficiency of nano fertilizers. Nitrogen is an important constituent of protoplasm, nucleic acid, proteins and chlorophyll. Phosphorus, on the other hand, is essential to the growth of roots, which is critical to the plant. According to Obiadallah *et al.* (2021) [11], the application of nano nitrogen and nano phosphorus provides the plant with proper nourishment, which aids in the development of additional leaves and a further increase in photosynthetic capability. He further stated that, nano nitrogen is crucial in the synthesis of growth hormones such as indole acetic acid (IAA), which subsequently promotes plant development. It was reported by Al-Abdali *et al.* (2021) [1] that, supply of nano fertilizers along with chemical fertilizers resulted in higher photosynthetic activity and further improved translocation of assimilates from source to sink.

3. Interaction effect

The interaction effect between the conventional fertilizers and nano fertilizers (Table 3) were found to be significant in case of the bulb fresh weight bulb^{-1} (g) during 2021-2022, 2022-2023 and in the pooled data. The treatment combination F_2N_3 had significantly higher bulb fresh weight bulb^{-1} over rest of the treatment combinations during the first and second year of experimentation and in the pooled mean except F_3N_3 during 2021-2022 and F_2N_5 during 2022-2023 which were found to be at par with the former treatment i.e. F_2N_3.

Table 1: Number of functional leaves plant^{-1} and bulb neck diameter (cm) of white onion as influenced by different treatments during 2021-2022; 2022-2023 and in the pooled data

Treatments	Number of functional leaves plant^{-1}			Bulb neck diameter (cm)		
	2021-2022	2022-2023	Pooled data	2021-2022	2022-2023	Pooled data
Conventional fertilizers						
F_1 - Control	5.81	6.97	6.39	1.50	1.43	1.47
F_2 - 100% RD of N and P + 100% RD of K	6.99	8.12	7.55	1.69	1.64	1.66
F_3 - 75% RD of N and P + 100% RD of K	6.86	8.11	7.48	1.66	1.62	1.64
F_4 - 50% RD of N and P + 100% RD of K	6.67	7.68	7.17	1.60	1.60	1.60
S.E.(m)±	0.04	0.04	0.03	0.01	0.01	0.01
C.D. at 5%	0.13	0.12	0.09	0.04	0.03	0.03
Nano fertilizers						
N_1- control	5.66	6.90	6.28	1.46	1.41	1.44
N_2- 25% RD of N through nano-urea + 25% RD of P through nano-phosphorous (2 sprays at 45 and 60 DAT)	6.47	7.63	7.05	1.56	1.54	1.55
N_3- 50% RD of N through nano-urea + 25% RD of P through nano-phosphorous (2 sprays at 45 and 60 DAT)	7.17	8.24	7.70	1.75	1.68	1.71
N_4- 25% RD of N through nano-urea + 50% RD of P through nano-phosphorous (2 sprays at 45 and 60 DAT)	6.67	7.82	7.24	1.62	1.59	1.60
N_5- 50% RD of N through nano-urea + 50% RD of P through nano-phosphorous (2 sprays at 45 and 60 DAT)	6.95	8.01	7.48	1.68	1.63	1.66
S.E.(m)±	0.04	0.04	0.04	0.01	0.02	0.01
C.D. at 5%	0.12	0.13	0.12	0.04	0.04	0.04
Interaction effects						
S.E.(m)±	0.09	0.09	0.08	0.03	0.03	0.03
C.D. at 5%	N.S	N.S	N.S	N.S	N.S	N.S

Table 2: Bulb fresh weight bulb^{-1} (g) and mean bulb yield (q ha^{-1}) of white onion as influenced by different treatments during 2021-2022; 2022-2023 and in the pooled data

Treatments	Bulb fresh weight bulb^{-1} (g)			Bulb yield (q ha^{-1})		
	2021-2022	2022-2023	Pooled data	2021-2022	2022-2023	Pooled data
Conventional fertilizers						
F_1 - control	33.52	36.16	34.84	60.90	59.66	60.28
F_2 - 100% RD of N and P + 100% RD of K	68.82	69.11	68.96	138.21	148.74	143.48
F_3 - 75% RD of N and P + 100% RD of K	67.71	68.41	68.06	132.90	143.11	138.00
F_4 - 50% RD of N and P + 100% RD of K	61.07	66.00	63.54	112.82	129.57	121.20
S.E.(m)±	0.31	0.29	0.17	1.66	2.64	1.46
C.D. at 5%	1.06	0.99	0.60	5.73	9.15	5.04
Nano fertilizers						
N_1- control	39.47	40.28	39.87	71.78	80.60	76.19
N_2- 25% RD of N through nano-urea + 25% RD of P through nano-phosphorous (2 sprays at 45 and 60 DAT)	55.56	57.23	56.40	97.53	107.69	102.61
N_3- 50% RD of N through nano-urea + 25% RD of P through nano-phosphorous (2 sprays at 45 and 60 DAT)	70.23	74.27	72.25	145.13	153.31	149.22
N_4- 25% RD of N through nano-urea + 50% RD of P through nano-phosphorous (2 sprays at 45 and 60 DAT)	59.05	60.32	59.68	112.10	119.60	115.85
N_5- 50% RD of N through nano-urea + 50% RD of P through nano-phosphorous (2 sprays at 45 and 60 DAT)	64.60	67.50	66.05	129.51	140.15	134.83
S.E.(m)±	0.40	0.49	0.51	4.67	3.19	4.64
C.D. at 5%	1.15	1.42	1.48	13.46	9.19	13.37
Interaction effects						
S.E.(m)±	0.80	0.99	1.03	9.34	6.38	9.28
C.D. at 5%	2.29	2.84	2.95	N.S	18.39	26.73

Table 3: Interaction effects between conventional fertilizers and nano fertilizers on bulb fresh weight bulb^{-1} (g) of white onion during 2021-2022; 2022-2023 and in the pooled data

Nano fertilizers ↓	Conventional fertilizers											
	2021-2022				2022-2023				Pooled data			
	F_1	F_2	F_3	F_4	F_1	F_2	F_3	F_4	F_1	F_2	F_3	F_4
N_1	13.62	52.89	48.99	42.38	18.27	39.97	57.66	45.22	15.94	46.43	53.33	43.80
N_2	33.29	64.31	63.87	60.76	35.30	64.38	67.83	61.41	34.30	64.35	65.85	61.09
N_3	45.16	81.90	79.92	73.92	49.94	85.29	80.24	81.60	47.55	83.60	80.08	77.76
N_4	35.74	68.77	70.00	61.67	37.08	73.19	66.33	64.67	36.41	70.98	68.17	63.17
N_5	39.81	76.23	75.75	66.62	40.19	82.71	69.98	77.10	40.00	79.47	72.87	71.86
S.E.(m)±	0.80				0.99				1.03			
C.D. at 5%	2.29				2.84				2.95			

The data given in the Table 4 shows that the mean bulb yield (q ha^{-1}) of white onion was influenced significantly due to interaction between conventional fertilizers and nano fertilizers during both the years of experimentation and in the pooled mean. Significantly higher bulb yield was produced by the treatment combination F_2N_3 over the rest of the treatment combinations excluding F_2N_5 during 2022-2023; F_2N_5 and F_3N_3 in the pooled mean which were statistically similar with F_2N_3.

The superior performance of the crop under the treatment combinations F_2N_3, F_3N_3 and F_2N_5 is due to the higher doses of essential nutrients, specifically nitrogen, phosphorus, and potassium, applied in F_2 (100% recommended dose of N and P + 100% recommended dose of K) using conventional fertilizers. When the conventional fertilizer treatment F_2 was supplemented with the nano fertilizer treatment N_3 [50% recommended dose of N through nano-urea + 25% recommended dose of P through nano-phosphorus (applied as two sprays at 45 and 60 days after transplanting)], the crop exhibited better growth characters. The improvement in growth characters led to the plants under the treatments F_2N_3, F_3N_3 and F_2N_5 becoming physiologically active resulting in production of more source. The greater amount of source available in these three combinations, compared to the other treatment combinations, inevitably leads to a relatively higher amount of sink within the plant which improved the yield attribute i.e. bulb fresh weight bulb^{-1} further enhancing the bulb yield. This is attributed to the beneficial effects of the major nutrients, provided in optimal amounts both from the soil and through foliar application.

Table 4: Interaction effects between conventional fertilizers and nano fertilizers on mean bulb yield (q ha^{-1}) of white onion during 2022-2023 and in the pooled data

Nano fertilizers ↓	Conventional fertilizers							
	2022-2023				Pooled data			
	F_1	F_2	F_3	F_4	F_1	F_2	F_3	F_4
N_1	44.40	96.89	97.03	84.07	41.62	92.81	93.58	76.73
N_2	57.40	123.30	133.70	116.37	56.17	117.88	128.60	107.78
N_3	75.40	197.80	174.53	165.50	76.10	194.28	169.42	157.08
N_4	58.20	142.17	145.80	132.23	61.47	137.18	142.88	121.87
N_5	62.90	183.53	164.47	149.70	66.05	175.22	155.53	142.52

S.E.(m)±	6.38	9.28
C.D. at 5%	18.39	26.73

Conclusion

From the two years of experimentation, it can be concluded that, the treatment F_2N_3 [100% RD of N and P + 100% RD of K and 50% RD of N through nano-urea + 25% RD of P through nano-phosphorous (2 sprays at 45 and 60 DAT)] showed higher growth attributes i.e. number of functional leaves plant^{-1} and bulb neck diameter as well as yield attributes i.e. bulb fresh weight bulb^{-1} and mean bulb yield in white onion crop.

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