PLANT SCIENCE TODAY
Vol x(x): xx–xx
https://doi.org/10.14719/pst.10064

eISSN 2348-1900

RESEARCH ARTICLE

Effectiveness of watering intervals and fertiliser types to increase the growth and productivity of shallots on dryland

Sri Anjar Lasmini[1*], Burhanuddin Haji Nasir[1], Nur Khasanah[1], Flora Pasaru[1], Idham Idham[1], Moh Hibban Toana[1], Dance Tangkesalu[2], Asgar Taiyeb[3] & Andriani Awaludin[4]

[1]Department of Agrotechnology, Tadulako University, Palu 94118, Indonesia
[2]Department of Agribusiness, Tadulako University, Palu 94118, Indonesia
[3]Department of Forestry, Tadulako University, Palu 94118, Indonesia
[4]Department of Crop Production, Tadulako University, Palu 94118, Indonesia

*Correspondence email - lasminisrianjar@gmail.com

Received: 15 June 2025; Accepted: 05 October 2025; Available online: Version 1.0: 05 March 2026

Cite this article: Sri AL, Burhanuddin HN, Nur K, Flora P, Idham I, Moh HT, Dance T, Asgar T, Andriani A. Effectiveness of watering intervals and fertiliser types to increase the growth and productivity of shallots on dryland. Plant Science Today (Early Access). https:/doi.org/10.14719/pst.10064

Abstract

Shallot cultivation in dryland areas is often constrained by limited water availability and low soil fertility. Deficiencies in organic matter and essential nutrients, particularly nitrogen, phosphorus and potassium, hinder optimal plant growth. To enhance the success of shallot farming under such conditions, strategies to improve water availability and nutrient supply are required, including periodic irrigation and the application of site-specific fertilisers. This study aimed to evaluate the effects of different watering intervals and fertiliser types on the growth and productivity of shallots in dryland ecosystems, serving as a reference for good agricultural practices. The experiment was conducted in Bulupountu Village, Sigi Biromaru District, Sigi Regency, Central Sulawesi, from May 2023 to November 2023. A split-plot experimental design was employed, with watering interval as the main plot factor (T_1: daily, T_2: every two days, T_3: every three days) and fertiliser type as the subplot factor (F_0: no fertiliser/control, F_1: organic fertiliser at recommended dose, F_2: inorganic fertiliser at recommended dose). The agronomic performance observed was plant height, number of leaves per plant, number of tillers, bulb weight per clump and yield per hectare of shallot. The results demonstrated that both watering interval and fertiliser type significantly influenced shallot growth and yield. The combination of watering every two days and application of 5 t/ha organic fertiliser yielded the most favourable results, producing up to 6.20 t/ha of shallots. These findings suggest that optimising water and nutrient management is essential for improving shallot productivity in dryland agriculture.

Keywords: *Allium ascalonicum*; marginal land; organic fertiliser; shallot cultivation; yield

Introduction

Shallot cultivation is an agricultural activity with high economic value, especially in tropical areas. In Central Sulawesi, Indonesia, shallot products are the raw material in the household industry, which is popularly known as Bawang Goreng (1, 2). The characteristics of the Bawang Goreng product are: perfectly cooked, golden yellow in colour, crispy, crunchy texture, appetising, does not smell rancid and has a distinctive onion aroma. It is made from shallots of the Lembah Palu variety (*Allium cepa* L. var. *aggregatum*). Based on a survey of shallots of the Lembah Palu variety shows that the number of bulbs for one clump of plants can reach an average of five cloves with an average weight of around 12.5 g, so that production per hectare reaches an average of 3.3 t. This production is still very low compared to the potential yield of 10–12 t/ha (3, 4).

One of the main challenges in shallot cultivation on dryland is the limited water availability and low soil fertility. Proper water and nutrient management are required to improve yield and ensure sustainable production under these conditions (5, 6). Central Sulawesi has quite extensive dryland with temperature fluctuations above 37 °C. The main problem of dryland is the limited availability of water, so the drought factor is one of the abiotic constraints that limit shallot production in dryland. In addition, dryland tends to be less fertile, poor in nutrients, low in organic matter and sandy. The lack of organic matter and nutrients such as nitrogen, phosphorus and potassium makes it difficult for plants to grow well. Efficient water utilisation in dryland is important, especially in uncertain climate conditions. Several studies have shown that shallots are very sensitive to water availability, especially during the bulb development process. Regular watering can significantly increase crop yield; conversely, inadequate watering can stunt plants and decrease production (7–9).

Shallots have moderate water requirements. Watering should be done carefully because shallots are not resistant to waterlogging, which can damage the roots. Ideally, irrigation is done when the soil begins to dry out, with a watering frequency of once a day during the early stages of growth and can be increased to twice a day towards the bulb formation phase. A drip irrigation system is one of the most efficient methods for maintaining soil moisture in dryland, because it can channel water directly to the root zone without being wasted through evaporation (10).

In addition to efficient water utilisation, the selection of fertiliser types also greatly determines the success of shallot cultivation. Dryland is generally poor in nutrients, so balanced fertiliser application is important to support plant growth. Shallots require the main nutrients during the plant growth process, such as nitrogen (N), phosphorus (P) and potassium (K). Basic fertilisers are generally given during land preparation before planting, for example, using NPK and organic fertilisers. The first follow-up fertilisation is carried out 10–15 days after planting, while the second fertilisation is carried out at the age of 30–35 days when the plants enter the tuber formation phase. Thus, the combination of organic and inorganic fertilisers provides the best results in plant cultivation on marginal land (11, 12).

Organic fertilisers such as compost and green manure can increase the soil's capacity to store water and improve soil structure so that it is more optimal in supporting root growth. Meanwhile, inorganic fertilisers, especially nitrogen (N), phosphorus (P) and potassium (K) fertilisers, provide nutrients in a form that is more easily absorbed by plants, thereby accelerating growth and increasing yields (13, 14). Inorganic fertilisers usually dissolve quickly in water, so that if given together or immediately after watering, plants can immediately absorb nutrients. Meanwhile, organic fertilisers take longer to decompose and release nutrients, but still require soil moisture so that microbes can decompose them. Proper watering will help the decomposition process of organic fertilisers.

Previous research has generally focused on a single aspect, either regulating watering frequency or partially applying specific fertilisers, without considering the relationship between plant growth phases and water and nutrient requirements. Furthermore, the irrigation technology used is still dominated by conventional methods such as manual watering, which wastes water and is less suitable for dry land conditions (15). The combination of irrigation and proper fertilisation will accelerate the absorption of nutrients by plants so that it can increase the productivity of shallots in dryland, especially in difficult environmental conditions (16, 17). Thus, to optimise shallot production in dryland, an integrated approach is needed between efficient water management and proper fertiliser application. The study aimed to determine the interval of water application and the type of fertiliser that is effective in increasing the growth and production of shallots as a reference in implementing good farming methods for shallot cultivation in dryland.

Materials and Methods

Study site and experimental design

The study was conducted in Bulupountu Jaya Village, located in Sigi Regency, Central Sulawesi, Indonesia, at an elevation of 120 m above sea level. The experimental site is characterised by inceptisol soil, distinguished by its acidic nature (pH < 6) and low organic matter content. The characteristics of the chemical and physical properties of the soil in the research area are described in Table 1. Climatic conditions in the area include a mean air temperature of 37.3 °C, an average annual relative humidity of 72.49 % and a mean annual precipitation of 41.10 mm^3. The research was carried out over six months, from May to November 2023.

A split-plot experimental design was employed, incorporating two treatment factors. The main plot factor consisted of three watering intervals: T_1 = daily, T_2 = once every two days and T_3 = once every three days. The subplot factor involved fertiliser application, comprising three levels: F_0 = no fertiliser (control), F_1 = organic fertiliser as per recommended dosage and F_2 = inorganic fertiliser as per recommended dosage. The factorial combination of these treatments resulted in nine treatment combinations, each replicated three times, yielding a total of 27 experimental units. Before planting shallots, the land is first ploughed using a hand tractor. The soil is ploughed to a depth of 20–30 cm until loose, then made into beds measuring 2 m × 4 m with a distance between plots of 30 cm. The soil cultivation is carried out two weeks before planting. Compost fertiliser was applied one week before planting at a dose of 5 t/ha by burying and then levelling, while inorganic NPK fertiliser was applied 14 days after planting according to the recommended dose of 200 kg/ha. The shallot seeds were planted with a spacing of 15 cm × 20 cm from north to south, with a distance between rows of plots of 0.60 m. The shallot seedlings used were the Lembah Palu variety (*A. cepa*). Watering was done in the morning or evening according to the treatment. Weeding was done manually as needed, while pest and disease control was carried out using the integrated pest control method for lowland vegetables.

Table 1. Chemical and physical properties of the soil

Soil properties	
pH (H_2O)	5.87
C-organic	0.75
C/N ration	7.58
Total N (%)	0.14
Total P (mg 100/g)	21.54
K_2O (mg 100/g)	27.64
CEC (meg 100/g)	14.30
Bulk Density (g/cm^3)	1.54
Permeability (cm/hour)	3.67
Porosity (%)	45

Data collection and analysis

Agronomic parameters evaluated in this study included plant height (cm), number of leaves (leaves/plant), number of tillers (tillers/plant), bulb diameter (mm), bulb weight per clump (g) and yield per hectare (t/ha) of shallot. For each variable, data were collected from 10 randomly selected clumps of shallot plants. Measurements of plant height, number of leaves and number of tillers were conducted at 49 days after planting (DAP). Plant height was measured from the base of the plant to the tip of the longest leaf using a measuring ruler. The number of leaves per plant was recorded manually, the number of tillers was counted directly from each clump, while the bulb diameter was measured by callipers.

Bulb weights, as well as yield per hectare, were assessed at harvest. Bulb weight was determined using a digital balance immediately after harvest. Subsequently, the bulbs were air-dried until a constant weight was obtained to determine dry biomass. The total weight of fresh shallot bulbs, excluding leaves and roots, was then extrapolated to estimate yield per hectare (t/ha). The data obtained were analysed using analysis of variance (ANOVA) appropriate for a split-plot design. Significant main and interaction effects were further examined through mean separation using the honestly significant difference (HSD) test at the 5 % probability level.

Results

Plant height and number of leaves

There was an interaction between the watering interval and the type of fertiliser on plant height and the number of leaves (Table 2). It was found that watering intervals and types of fertilisers had a significant effect on the plant height and number of leaves (Table 2). When the data in terms of plant height and number of leaves were evaluated, it was found that the highest plant height mean value (41.73 cm) and number leaves mean value (12.7 leaves/plant), were reached in the combined applications of watering intervals once every two days and organic fertiliser according to recommendations, so the treatment of the watering interval and the type of fertiliser played a role in increasing plant height and the number of shallot leaves.

Table 2. The effect of different watering intervals and types of fertilisers on plant height and the number of leaves of the shallot

Variable	T × F	F_0	F_1	F_2	HSD 5 %
Plant height	T_1	q34.25b	r36.83a	q36.98a	1.64
	T_2	p38.99b	p41.73a	p40.90a	
	T_3	p39.19a	q39.23a	p40.08a	
	HSD 5%		1.64		
Number leaves	T_1	q8.80b	q9.70a	q9.90a	0.84
	T_2	p9.77b	p12.07a	p11.37a	
	T_3	p9.83a	q10.07a	q10.40a	
	HSD 5 %		0.84		

Numbers followed by the same letters in columns (p, q, r) and rows (a, b, c) are not significantly different at the 5% level as assessed by the honestly significant difference (HSD), T_1: daily, T_2: once every two days and T_3: once every three days, F_0: no fertiliser (control), F_1: organic fertiliser as per recommended dosage and F_2: inorganic fertiliser as per recommended dosage.

Number of tillers

There was no interaction between the watering interval and the type of fertiliser on the number of tillers, but the watering interval and the type of fertiliser had an individual effect (Table 3). The watering interval of once every two days showed the largest number of tillers (7.02 tillers) and was significantly different from the watering intervals of daily and once every three days. The type of organic fertiliser showed the largest number of tillers (6.81 tillers), which was not significantly different from inorganic fertiliser, but significantly different from no fertiliser (Table 3).

Table 3. The effect of different watering intervals and the type of fertiliser on the number of tillers (tillers)

Watering interval	Number of tillers
T_1	6.03b
T_2	7.02a
T_3	5.18c
HSD 5 %	0.69
Types of fertilisers	
F_0	5.04b
F_1	6.81a
F_2	6.38a
HSD 5 %	0.69

Numbers followed by the same letters in columns (p, q, r) and rows (a, b, c) are not significantly different at the 5 % level as assessed by the honestly significant difference (HSD), T_1: daily, T_2: once every two days and T_3: once every three days, F_0: no fertiliser (control), F_1: organic fertiliser as per recommended dosage and F_2: inorganic fertiliser as per recommended dosage.

Bulb diameter

The watering interval and fertiliser type had no significant effect on bulb diameter. However, watering every two days and applying organic fertiliser tended to produce the highest bulb diameter (25.33 mm) compared to the other treatments (Fig. 1).

Bulb weight per clump and yield per hectare of shallots

There was an interaction between the watering interval application and the type of fertiliser on the bulb weight and yield per hectare of shallots (Table 4). Table 4 shows the interaction between the watering interval and the type of fertiliser on the parameters of bulb weight and yield per hectare of shallot, so that the treatment of watering interval and fertiliser type plays a role in increasing bulb weight and yield per hectare of shallot. The T_2F_1 combination treatment showed the highest bulb weight (22.87 g) and the highest shallot yield per hectare (6.20 t/ha), significantly different from other treatments.

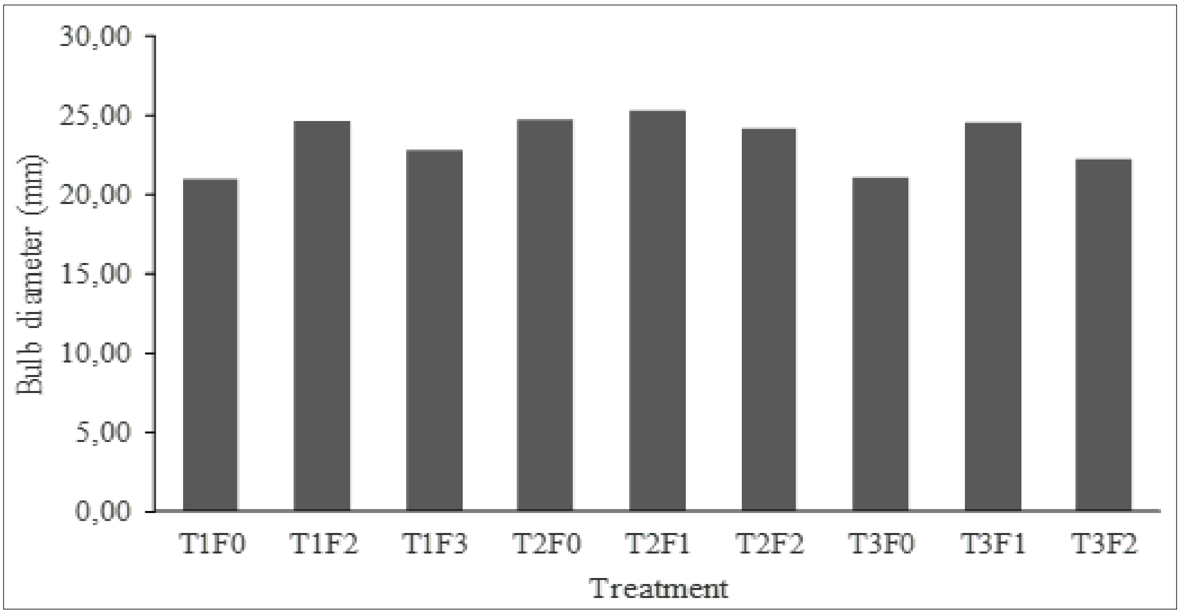

Fig. 1. Average diameter of shallot bulbs at various watering intervals and fertiliser types. Note: T_1: daily, T_2: once every two days and T_3: once every three days, F_0: no fertiliser (control), F_1: organic fertiliser as per recommended dosage and F_2: inorganic fertiliser as per recommended dosage.

Table 4. The effect of different water application intervals and types of fertilisers on the bulb weight and yield per hectare of shallot

Variable	T × F	F_0	F_1	F_2	HSD 5 %
Bulb weight	T_1	q11.85b	r14.85a	r15.31a	1.49
	T_2	p14.40b	p22.87a	p21.39a	
	T_3	p14.24b	q18.57a	q19.30a	
	HSD 5 %		1.49		
Yield per hectare	T_1	q3.16b	r3.96a	r4.08a	0.34
	T_2	p3.84c	p6.20a	p5.70b	
	T_3	p3.80b	q4.95a	q5.15a	
	HSD 5 %		0.34		

Numbers followed by the same letters in columns (p, q, r) and rows (a, b, c) are not significantly different at the 5 % level as assessed by the honestly significant difference (HSD), $\mathbf{T_1}$: daily, $\mathbf{T_2}$: once every two days and $\mathbf{T_3}$: once every three days, $\mathbf{F_0}$: no fertiliser (control), $\mathbf{F_1}$: organic fertiliser as per recommended dosage and $\mathbf{F_2}$: inorganic fertiliser as per recommended dosage.

Discussion

The results of the study showed that there was an interaction between the treatment of watering interval and fertiliser type on the parameters of plant height and the number of leaves, bulb weight per clump and yield per hectare of shallot, while there was no interaction on the number of tillers of shallot so that the treatment of watering interval and fertiliser type played a role in increasing the growth and yield of shallot (Table 2–4). Previous studies reported that the amount of irrigation water and nitrogen fertiliser had a significant effect with a probability level of 1 % on the yield and components of shallot yields (18).

The number of tillers in shallots does not show a significant interaction between watering interval and fertiliser type because this trait is more controlled by genetic and physiological factors than by environmental conditions. Hormonal regulation, particularly the balance of auxin, cytokinin and gibberellin, is known to play a significant role in regulating lateral shoot formation, so variations in water and nutrient availability have little impact (19, 20). Furthermore, differences in tiller potential are also determined by varietal traits and cultivar metabolite profiles, not solely by fertiliser or water availability (21). Thus, the stability of tiller number reflects the dominance of internal plant mechanisms over the influence of external agronomic treatments.

Optimal water conditions must support good plant growth and the irrigation schedule must be adjusted to climate conditions, especially depending on the amount and distribution of rainfall (10, 22). High rainfall can inhibit the photosynthesis process in shallot plants, because the energy of sunlight is blocked by clouds and causes excessive water availability which can inhibit the photosynthesis process for plant growth, on the other hand, water stress can be detrimental because it will interfere with the metabolic process in the plant body so that the impact is hampered from entering the next vegetative phase (23–27). In shallot cultivation, optimal soil moisture is usually maintained at 60–80 % of field capacity, because below 50 % the plant begins to experience drought stress characterised by stunted growth and decreased bulb weight (28, 29).

The frequency and duration of irrigation are critical determinants of plant growth and development. In the present study, variations in watering intervals significantly influenced plant height, leaf number and overall productivity. This is supported by previous findings indicating that optimal irrigation timing enhances hormonal activity within cell walls, thereby promoting the synthesis of sugars that drive cell enlargement and vacuole formation (30, 31). Vacuoles, once activated, absorb substantial amounts of water, improving cell turgidity and contributing to robust vegetative growth (32). These hormonal mechanisms also facilitate cell elongation, thickening of cell walls and the formation of new cells, ultimately accelerating the development of shoots, leaves and root systems.

However, maintaining an appropriate water balance is essential throughout all growth phases. Both insufficient and excessive water can negatively impact plant physiological processes, leading to abnormal growth patterns and reduced yields (33). Over-irrigation, for example, may cause soil oxygen depletion, resulting in impaired root respiration and potential root damage (34). This highlights the importance of tailoring irrigation practices to the specific water requirements of the crop and prevailing environmental conditions to optimise plant health and productivity.

The low production of the Palu Valley shallot variety is due to the fact that most shallots are grown on dryland with quite unique agro-ecosystem characteristics, characterised by relatively low rainfall and uneven distribution throughout the year, low organic matter content due to intensive land cultivation and minimal organic inputs. The T_2F_1 combination (watering every two days + organic fertiliser) provides the best results due to the positive interaction between optimal water availability and improved soil quality due to the application of organic fertiliser, which causes the soil structure to become loose (Table 4). Watering every two days maintains soil moisture without causing hypoxia, allows for efficient root respiration and provides energy (ATP) to support cell division and elongation (35). At the same time, organic fertiliser improves soil structure, increases cation exchange capacity and enriches soil microbial activity, thereby accelerating nutrient mineralisation (36). These conditions increase the efficiency of nitrogen and phosphorus absorption, which play an important role in chlorophyll formation, energy metabolism and protein synthesis. Biochemically, increased nutrient availability and photosynthetic activity encourage carbohydrate accumulation and assimilate translocation to tubers, resulting in higher yields compared to other treatment combinations (37).

The highest yields in the T_2F_1 combination indicate that this treatment is able to provide more balanced environmental conditions compared to other treatments. In T_1F_1 (watering once a day + organic fertiliser), despite greater water availability, excessively high soil moisture tends to reduce oxygen diffusion in the root zone, resulting in suboptimal root respiration. This can reduce nutrient uptake efficiency even when organic fertiliser is adequate. Conversely, in T_3F_1 (watering once every three days + organic fertiliser), plants experience a longer period of drought stress, disrupting photosynthetic activity, resulting in lower production (38).

Watering intervals and effective fertiliser types are important aspects of implementing good agricultural practices for shallot cultivation. Proper water management can ensure that plants get sufficient water supply according to the growth phase of the shallot, while proper fertilisation will meet the nutritional needs of plants for optimal growth. The combination of these two aspects not only increases the productivity and quality of shallots but also contributes to the sustainability of environmentally friendly agriculture. The implementation of good agricultural practices will help shallot farmers achieve maximum results while maintaining the balance of the ecosystem and the sustainability of natural resources.

Conclusion

Watering interval and fertiliser type significantly influence the growth and productivity of shallots in dryland conditions. The combination of watering once every two days with the application of organic fertiliser proved to be the most effective strategy. This treatment resulted in a shallot yield of 6.20 t/ha, indicating that it is a sustainable and efficient approach for shallot cultivation in dryland areas.

Acknowledgements

The authors gratefully acknowledge the Ministry of Education, Culture, Research and Technology, Republic of Indonesia, for financial support of this research under Contract Nos. 169/E5/PG.02.00.PL/2023 and 1460.b/UN28.2/PL/2023.

Authors' contributions

SAL contributed to conceptualisation, investigation, methodology and drafting of the original manuscript. BHN contributed to formal analysis and methodology. FP contributed to methodology, review and editing. AT contributed to data curation, formal analysis, investigation and validation. AA contributed to investigation and data curation. MHT, NK, II and DT contributed to article editing. All authors read and approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

References

1. Ansar M, Paiman. Keragaan teknologi untuk meningkatkan produktivitas bawang merah varietas Lembah Palu: Sebuah review (performance of technology to increase the productivity of shallots of the Palu Valley variety: A review). J. Hort. Indones. 2023;14(1):9-16. https://doi.org/10.29244/jhi.14.1.9-16
2. Maemunah M, Syamsiar S, Mustakim M. Pertumbuhan dan hasil bawang merah Lembah Palu pada pemberian berbagai konsentrasi AB mix. Agroland. 2024;31(2):135-40. https://doi.org/10.22487/agrolandnasional.v31i2.2171
3. BPS Statistics Indonesia. Statistical yearbook of Indonesia: Harvested area of vegetables by province and kind of plant (ha), 2022 and 2023. Vol. 52. BPS Statistics Indonesia; 2024. p.1-804.
4. BPS-Statistics Sulawesi Tengah Province. Sulawesi Tengah province in figures 2024: Production of vegetables by regency/municipality and kind of plant in Sulawesi Tengah Province, 2022 and 2023. Vol. 54. Palu: BPS-Statistics Sulawesi Tengah Province; 2024. p.1-801.
5. Sansan OC, Ezin V, Ayenan MAT, Chabi IB, Adoukonou-Sagbadja H, Saïdou A, et al. Onion (*Allium cepa* L.) and drought: Current situation and perspectives. Scientifica. 2024;2024:1-12. https://doi.org/10.1155/2024/6853932
6. Igbadun HE, Ramalan AA, Oiganji E. Effects of regulated deficit irrigation and mulch on yield, water use and crop water productivity of onion in Samaru, Nigeria. Agric. Water Manag. 2012;109:162-9. https://doi.org/10.1016/j.agwat.2012.03.006
7. Zeleke K, Nendel C. Yield response and water productivity of soybean (*Glycine max* L.) to deficit irrigation and sowing time in south-eastern Australia. Agric. Water Manag. 2024;296:108815. https://doi.org/10.1016/j.agwat.2024.108815
8. Zhang B, Yan S, Li B, Wu S, Feng H, Gao X, et al. Combining organic and chemical fertiliser plus water-saving system reduces environmental impacts and improves apple yield in rainfed apple orchards. Agric. Water Manag. 2023;288:108482. https://doi.org/10.1016/j.agwat.2023.108482
9. Mubarak I. Improving water productivity and yield of onion crop by combining early planting and straw mulch under different irrigation levels in dry Mediterranean region. Adv. Hortic. Sci. 2020;34:49-60. https://doi.org/10.13128/AHSC-8401
10. Guo H, Li S. A review of drip irrigation's effect on water, carbon fluxes and crop growth in farmland. Water. 2024;16(15):2206. https://doi.org/10.3390/w16152206
11. Kalika-Singh S, Ansari A, Maharaj G. Vegetable crop cultivation using vermicompost in comparison to chemical fertilisers: A review. Agric. Rev. 2022;43:1-5. https://doi.org/10.18805/ag.RF-234
12. Teklehaimanot T, Zerfu A, Shumuye M. Response of onion (*Allium cepa* L.) bulb to the combined effect of vermicompost and mineral fertiliser under irrigated soil condition in Raya Azobo and Kilte-Awulaelo districts South and Eastern Tigray, Ethiopia. Agric. Rev. 2025;46:147-57. https://doi.org/10.18805/ag.RF-298
13. Kakar K, Xuan TD, Noori Z, Aryan S, Gulab G. Effects of organic and inorganic fertiliser application on growth, yield and grain quality of rice. Agriculture. 2020;10(11):544. https://doi.org/10.3390/agriculture10110544
14. Liu Y, Lan X, Hou H, Ji J, Liu X, Lv Z. Multifaceted ability of organic fertilisers to improve crop productivity and abiotic stress tolerance: Review and perspectives. Agronomy. 2024;14(6):1141. https://doi.org/10.3390/agronomy14061141
15. Bekele S, Tilahun K. Regulated deficit irrigation scheduling of onion in a semiarid region of Ethiopia. Agric. Water Manag. 2007;89(1-2):148-52. https://doi.org/10.1016/j.agwat.2007.01.002
16. Manik TK, Timotiwu PB, Mua'ddin M. Shallot growth and yield supported by irrigation and nitrogen application in utilizing dry land area in Mesuji, Lampung Province, Indonesia. Sains Tanah J. Soil Sci. Agroclimatol. 2023;20(1):100. https://doi.org/10.20961/stjssa.v20i1.70711
17. Mu'addin M, Timotiwu PB, Manik TK, A A. Applied nitrogen fertilization and irrigation on improving shallot (*Allium ascolanicum* L.) growth and yield on dry land in Mesuji, Lampung Province, Indonesia. Int. J. Agric. Tech. 2023;3:1-10. https://doi.org/10.33425/2770-2928.1016
18. Piri H, Naserin A. Effect of different levels of water, applied nitrogen and irrigation methods on yield, yield components and IWUE of onion. Sci. Hortic. 2020;268:109361. https://doi.org/10.1016/j.scienta.2020.109361
19. Atif MJ, Ahanger MA, Amin B, Ghani MI, Ali M, Cheng Z. Mechanism of *Allium* crops bulb enlargement in response to photoperiod: A review. Int. J. Mol. Sci. 2020;21(4):1325. https://doi.org/10.3390/ijms21041325
20. Yamazaki H, Shiraiwa N, Itai A, Honda I. Involvement of gibberellins in the regulation of tillering in Welsh onion (*Allium fistulosum* L.). Hortic. J. 2015;84(4):334-41. https://doi.org/10.2503/hortj.MI-050
21. Basundari FRA, Sulistyaningsih E, Murti RH, Nuringtyas TR. Comparative metabolite profiling in single and multiple bulb cultivars of shallot (*Allium cepa* L. Aggregatum group). J. Saudi Soc. Agric. Sci. 2024;23(8):521-32. https://doi.org/10.1016/j.jssas.2024.06.002
22. Merchán D, Sanz L, Alfaro A, Pérez I, Goñi M, Solsona F, et al. Irrigation implementation promotes increases in salinity and nitrate concentration in the lower reaches of the Cidacos River (Navarre, Spain). Sci. Total Environ. 2020;706:135701. https://doi.org/10.1016/j.scitotenv.2019.135701

23. Moore CE, Meacham-Hensold K, Lemonnier P, Slattery RA, Benjamin C, Bernacchi CJ, et al. The effect of increasing temperature on crop photosynthesis: From enzymes to ecosystems. J. Exp. Bot. 2021;72 (8):2822-44. https://doi.org/10.1093/jxb/erab090

24. Zhao W, Liu L, Shen Q, Yang J, Han X, Tian F, et al. Effects of water stress on photosynthesis, yield and water use efficiency in winter wheat. Water. 2020;12(8):2127. https://doi.org/10.3390/w12082127

25. Yu J, Zhang Y, Wang Y, Luo X, Liang X, Huang X, et al. Ecosystem photosynthesis depends on increased water availability to enhance carbon assimilation in semiarid desert steppe in northern China. Glob. Ecol. Conserv. 2022;38:e02202. https://doi.org/10.1016/j.gecco.2022.e02202

26. Manghwar H, Hussain A, Alam I, Khoso MA, Ali Q, Liu F. Waterlogging stress in plants: Unraveling the mechanisms and impacts on growth, development and productivity. Environ. Exp. Bot. 2024;221:105824. https://doi.org/10.1016/j.envexpbot.2024.105824

27. Mancosu N, Snyder R, Kyriakakis G, Spano D. Water scarcity and future challenges for food production. Water. 2015;7(3):975-92. https://doi.org/10.3390/w7030975

28. El-Metwally I, Geries L, Saudy H. Interactive effect of soil mulching and irrigation regime on yield, irrigation water use efficiency and weeds of trickle-irrigated onion. Arch. Agron. Soil Sci. 2022;68 (8):1103-16. https://doi.org/10.1080/03650340.2020.1869723

29. Zheng J, Huang G, Wang J, Huang Q, Pereira LS, Xu X, et al. Effects of water deficits on growth, yield and water productivity of drip-irrigated onion (*Allium cepa* L.) in an arid region of Northwest China. Irrig. Sci. 2013;31(5):995-1008. https://doi.org/10.1007/s00271-012-0378-5

30. Wagg C, Hann S, Kupriyanovich Y, Li S. Timing of short period water stress determines potato plant growth, yield and tuber quality. Agric. Water Manag. 2021;247:106731. https://doi.org/10.1016/j.agwat.2020.106731

31. Zin El-Abedin TK, Mattar MA, Alazba AA, Al-Ghobari HM. Comparative effects of two water-saving irrigation techniques on soil water status, yield and water use efficiency in potato. Sci. Hortic. 2017;225:525-32. https://doi.org/10.1016/j.scienta.2017.07.044

32. Abdelkhalik A, Pascual B, Nájera I, Baixauli C, Pascual-Seva N. Regulated deficit irrigation as a water-saving strategy for onion cultivation in Mediterranean conditions. Agronomy. 2019;9(9):521. https://doi.org/10.3390/agronomy9090521

33. Karandish F, Šimůnek J. Two-dimensional modeling of nitrogen and water dynamics for various N-managed water-saving irrigation strategies using HYDRUS. Agric. Water Manag. 2017;193:174-90. https://doi.org/10.1016/j.agwat.2017.07.023

34. Paikaray S, Mahajan T. Hydrogeochemical processes, mobilization controls, soil-water-plant-rock fractionation and origin of fluoride around a hot spring affected tropical monsoonal belt of eastern Odisha, India. Appl. Geochem. 2022;147:105521. https://doi.org/10.1016/j.apgeochem.2022.105521

35. Taiz L, Møller IM, Murphy A, Zeiger E. Plant physiology and development. 7th ed. Oxford: Oxford Univ. Press; 2023. https://doi.org/10.1093/hesc/9780197614204.001.0001

36. Lehmann J, Kleber M. The contentious nature of soil organic matter. Nature. 2015;528(7580):60-8. https://doi.org/10.1038/nature16069

37. Cárceles Rodríguez B, Durán-Zuazo VH, Soriano Rodríguez M, García-Tejero IF, Gálvez Ruiz B, Cuadros Tavira S. Conservation agriculture as a sustainable system for soil health: A review. Soil Syst. 2022;6 (4):87. https://doi.org/10.3390/soilsystems6040087

38. Aytenew M, Bore G. Effects of organic amendments on soil fertility and environmental quality: A review. J. Plant Sci. 2020;8(5):112. https://doi.org/10.11648/j.jps.20200805.12

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

Copyright: © The Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited (https://creativecommons.org/licenses/by/4.0/)

Publisher information: Plant Science Today is published by HORIZON e-Publishing Group with support from Empirion Publishers Private Limited, Thiruvananthapuram, India.