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Growth, bulb yield, water productivity and quality of onion (*Allium cepa* L.) as affected by deficit irrigation regimes and exogenous application of plant bio–regulators

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ABSTRACT

Effect of plant bio–regulators (PBRs) *viz*., potassium nitrate (KNO_3, 15 g L^{-1}), thio–urea (TU, 500 ppm), salicylic acid (SA, 10 μM), gibberellic acid (GA_3, 25 ppm) and sodium benzoate (SB, 150 mg L^{-1}) for two years (2015–17) under various levels of deficit irrigation created using line source sprinkler system (LSS) was evaluated in onion (*Allium cepa* L.). The crop could sustain little water deficits and its bulb yield declined to 0.84, 0.66, 0.48, 0.35, 0.24 and 0.16 when irrigation water (IW) applied equalled 0.85, 0.70, 0.55, 0.40, 0.25 and 0.10 times the pan evaporation (CPE) against maximum yield at full irrigation (IW:CPE 1.00). Application of PBRs helped to mitigate the water stress through maintenance of leaf water content, modulating the canopy temperature and better water usage thereby improving average bulb yields by 10.1–25%. Especially KNO_3 and TU were more effective under low to medium water deficits. The water productivity ranged between 7.78 and 9.61 with PBRs against 7.36 kg m^{-3} under control. The overall water saving was 18.3, 25.7, 48.4 and 63.8% with PBRs namely GA_3, SA, TU and KNO_3, respectively. The marketable quality monitored in terms of bulb weight, geometric mean diameter and sphericity was significantly reduced with water deficits while it improved with PBRs. Among the other physicochemical and functional quality characteristics of the onion bulb, rehydration ratio, protein content, total soluble sugar, total phenolics content and pyruvic acid were lowered by water deficits. These were improved significantly with PBRs. Thus it was concluded that combining PBRs like KNO_3 and TU can further facilitate to implement deficit irrigation technology for sustaining productivity and quality of onion under water scarce conditions.

1. Introduction

Onion is one of the major vegetable crops grown in arid and semi–arid regions across the world. India is second largest onion producer contributes about one–fifth of the world production. Though cultivated both during and post monsoon seasons (Vanitha et al., 2013), latter is preferred by farmers for its superior quality, larger and uniform bulb size, better storage and fewer incidences of diseases. However, this crop is vulnerable to midseason drought as a consequence of erratic rainfall and low storage of moisture due to shallowness of soils which are insufficient to meet crop water demands (Pelter et al., 2004; El Balla et al., 2013). Therefore, supplemental irrigation continues to be the key strategy to achieve its yield potential and stabilized production (Zheng et al., 2013; Pejic et al., 2014). Anyhow, scarcity of water being a main constraint for its production, the priority should be on the adoption of appropriate irrigation strategies those help in saving irrigation water. Among the various techniques proposed, deficit irrigation provides a means of reducing water consumption while minimizing adverse effects on yield (Zhang et al., 2004; Mermoud et al., 2005). Here the crop is exposed to a certain level of water stress either during a particular period or throughout the growing season. However, the deficit irrigation has been tested in most of agricultural crops which are able to sustain *via* extracting water from comparatively lower soil depth during irrigation limiting situations (Ali et al., 2007). Being shallow–rooted crop, onion is more sensitive to water stress (Rao, 2016) and therefore requires frequent and light irrigations (Koriem et al., 1994). Therefore, deficit irrigation may have limited feasibility in onion but the same needs to be established. Keeping this in view the first objective of this study was to

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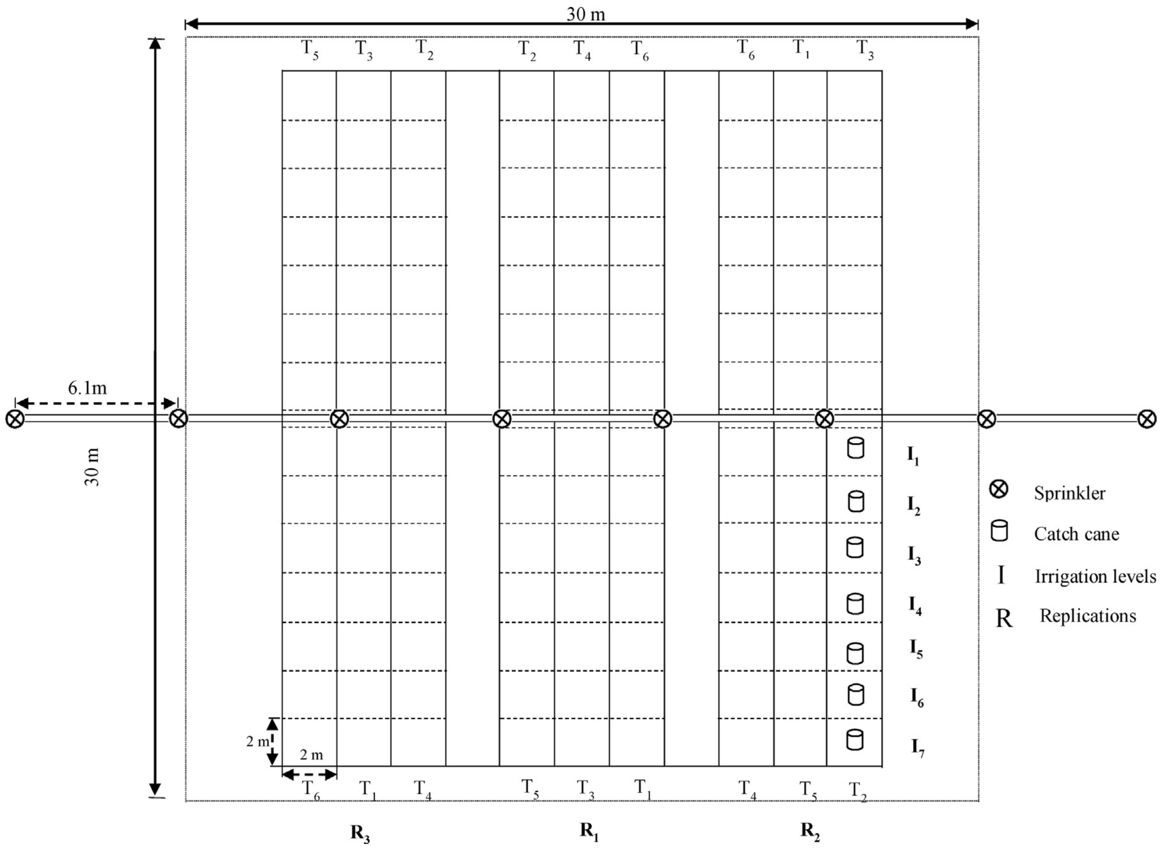

Fig. 1. Field layout of line source sprinkler system (T_1–T_6 denote KNO_3, TU, SA, GA_3, SB and control; I_1–I_7 denote IW: CPE 1.00, 0.85, 0.70, 0.55, 0.40, 0.25 and 0.10, respectively).

evaluate the impact of deficit irrigation levels on yield and quality of onion bulbs.

For promotion of growth and development under water stress conditions, exogenous application of plant bio–regulators (PBRs) and other nutrient supplements have been tried under both controlled and actual field conditions (Hassanein et al., 2015; Ratnakumar et al., 2016; Srivastava et al., 2016). These promote the ability of plants to cope with the stress conditions by mediating growth, development, nutrient allocation and source sink transitions. Mainly the PBRs with thiol–groups, which are involved in redox signalling and help to improve phloem translocation of photosynthate in plants and thereby alleviating salinity and drought stress in cereals, pulses and spices crops (Bhunia et al., 2015; Ratnakumar et al., 2016; Wakchaure et al., 2016a). Phenolic compound salicylic acid (SA) is an important signal transducer for mediating plant tolerance against the different abiotic stresses through regulation of physiological processes such as photosynthesis, antioxidant defense system, nitrogen metabolism, proline metabolism, production of glycinebetaine (GB) and plant–water relations under stress conditions (Khan et al., 2015). Potassium (K) is key element for crop growth, which improves yield and tolerance to drought by regulating turgor pressure and photosynthesis; translocation of cations and enzymes activation (Raza et al., 2013). The plant hormone gibberellin (GA_3) is a natural diterpenoid which promotes growth related physiological processes in plants. Sodium benzoate, a hydroxyl radical scavenger which protects the plant against oxidative damage under stress condition by inhibiting the ethylene synthesis thereby improving the seed yield of forage cowpea and wheat (Beltrano et al., 1999; Kumar et al., 2014). Overall, these reports signify the beneficial role of exogenous application of PBRs in regulation of physiological processes, plant—water relations and induction of antioxidant defence mechanism essential for plant tolerance to abiotic stresses. Thus, deficit irrigation is now being proposed for sustaining crop productivity and supplementing plant bio–regulators (PBRs) can further help to mitigate water stress (Wakchaure et al., 2016b). However, their impacts are yet to be evaluated for shallow rooted vegetable crops. Onion (*Allium cepa* L.) is one such crop that is often grown under water scarcity conditions. There is general lack of knowledge on relative response of PBRs on onion particularly for alleviation of water stress under field conditions. Therefore, some of the selected PBRs were tested for their role in mitigating stress specifically their interactive effects under varied moisture regimes in terms of performance of onion and its quality characteristics.

2. Material and methods

2.1. Experimental site and treatments

A field experiment was carried at the research farm of ICAR–National Institute of Abiotic Stress Management (NIASM), Baramati in Pune district of Maharashtra, India (18°09′N, 74°30′E and 560 MAMSL), during the post monsoon season (November–April) of two consecutive years (2015–2017). The black soil ($\leq$40 cm depth) of the experimental site was sandy clay in texture (sand, silt, clay, 56.1, 8.0, 35.9%, respectively), its pH (1: 2.5 soil: water suspension) was 8.2; EC 0.26 dS m^{-1}; organic matter 6.6 g kg^{-1}; available N, P, K 176, 25 and 148 kg ha^{-1}, respectively. The site characterized by low and erratic rainfall and is highly susceptible to drought. The long term average annual rainfall is 588 mm mainly restricted to south–west monsoon (71%) and retreating monsoon (22%) of which, post monsoon onion growing season receives less than 20 mm rainfall (Saha et al., 2015). Annual USWB open pan evaporation averages 1965 mm (Minhas