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On identifying smart water stress mitigating agent in deficit irrigation for groundnut

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Abstract
This study examined efficacy of KCl vis-à-vis humic acid (HA) as water stress mitigating agents in deficit irrigation and their effectiveness on leaf area index, plant height and dry matter production. The experiment on groundnut-VRI 8 variety was conducted at Agricultural College and Research Institute, Madurai, Tamil Nadu, India with Randomized Block Design consisting of ten treatments in three replications through drip irrigation system. Treatments were imposed to study the effects of deficit irrigation regimes, foliar application of KCl and humic acid so as to identify smart water stress mitigating agent between KCl and humic acid in face of deficit irrigation. The experimental study has demonstrated that KCl has emerged as smart water stress mitigating agent with an appreciable quantum of saving in irrigation water and its use efficiency in identifying an optimal deficit irrigation regime T_5 (75% ET_c + 1% KCl) though outperformed its counterpart of humic acid (HA).

Keywords: *Arachis hypogaea*, humic acid (HA), Irrigation, Treatments, groundnut

Introduction

Drip irrigation is a precise application of irrigation water to the root zone of the plant that saves water to a larger extent among all pressurized irrigation systems. Now, the focus has been shifted to deficit irrigation aimed at reducing the amount of water required for the crop without much reduction in yield (Hargreaves and Samani (1984) [12]; Mannocchi and Mecarelli (1994) [16]; English and Raja (1996) [7]; FAO, 2002 [9]; Fereres and Soriano (2007) [10]; Capra *et al.*, (2008) [5]; Geerts and Raes (2009) [11]; Rodrigues and Pereira (2009) [19]; Sampathkumar *et al.*, (2014) [20]; Yaseen *et al.*, (2014) [28]; Soni *et al.*, (2019) [22]; Sivarasan *et al.*, (2022) [21]. Drip irrigation at 100% Pan Evaporation (PE) with 100% Recommended Dose of fertilizers (RDF) as Water Soluble Fertilizer (WSF) recorded significantly higher plant height (41.17 cm) as compared to micro-sprinkler irrigation as well as surface irrigation (Soni *et al.*, 2017) [24]. The objective of the present study was to examine the extent to which foliar application of KCl and humic acid (HA) mitigate water stress caused by deficit irrigation in groundnut through drip irrigation system.

Groundnut is the leguminous oilseed crop known as *Arachis hypogaea* L. having ever growing demand for both human and animal feed - edible oil and protein. It is a short herbaceous annual crop belonging to the family *Leguminosae*. Innovations in development of groundnut varieties have been on yield maximization, crop duration and pest and disease tolerance affecting plant growth characteristics mainly, plant height, dry matter production and leaf area index. Groundnut being a warm season crop requires abundant sunshine for normal development at different stages of crop growth as evident from crop development and maturity period mainly dependent on the temperature (De Waele and Swanevelder 2001) [6]. Deficit irrigation causes water stress adversely in soil fertility, moisture availability during flowering and pod formation stages through photosynthesis and respiration affecting thus dry matter production and its accumulation. Water stress management practices in deficit irrigation assume greater significance when it comes to groundnut (Soni *et al.*, 2016) [23]. This present study examined the role of mitigation in deficit irrigation practices and its effect on growth parameters of groundnut.

Materials and Methods

Field Experiment: Experiment was conducted at Agricultural College and Research Institute, Madurai, Tamil Nadu, India during December 2021 - March 2022.

The experiment site is geographically located at 9°96' N latitude and 78°20' E longitude at an altitude of 147 m above mean sea level. The meteorological parameters averaged over 25 years revealed that a mean annual rainfall of 850 mm was received in 46 rainy days. Out of which, 39.8% was distributed during South West Monsoon (SWM), 42.0% during North East Monsoon (NEM), 2.1% during Winter and 16.1% during Summer. The mean daily maximum and minimum temperatures were 34.57 ºC and 22.68 ˚C respectively. The mean daily pan evaporation was 5.45 mm with the mean relative humidity of 88.24%. The soil type of the experimental field is sandy clay loam.

The experiment was laid out in Randomized Block Design with three replications. The treatment details are

T_1: Irrigation at 100% ET_c.
T_2: Irrigation at 75% ET_c.
T_3: Irrigation at 50% ET_c.
T_4: Irrigation at 100% ET_c + Foliar spray of 1% KCl at 30 DAS and 45 DAS.
T_5: Irrigation at 75% ET_c + Foliar spray of 1% KCl at 30 DAS and 45 DAS.
T_6: Irrigation at 50% ET_c + Foliar spray of 1% KCl at 30 DAS and 45 DAS.
T_7: Irrigation at 100% ET_c + Foliar spray of 1% humic acid at 30 DAS and 45 DAS.
T_8: Irrigation at 75% ET_c + Foliar spray of 1% humic acid at 30 DAS and 45 DAS.
T_9: Irrigation at 50% ET_c + Foliar spray of 1% humic acid at 30 DAS and 45 DAS.
T_{10}: Control (Surface irrigation 0.8 IW/CPE).

Irrigation Regime

Deficit irrigation imposed through drip method. Drip irrigation was scheduled as once in three days. Deficit irrigation was started from 15 DAS of groundnut crop based on crop evapotranspiration (ET_c) as calculated using $ET_c = E_p \times K_p \times K_c$

Where,
ET_c = Evapo-transpiration of crop (mm)
K_p = Pan factor (0.80) (FAO, 1998)
E_p = Pan Evaporation (mm)
K_c = Crop coefficient (FAO, 1998)

Water Stress Mitigating Agents

Along with the deficit irrigation regime treatments, water stress mitigating agents through foliar spray of 1% KCl and 1% humic acid were imposed at 30 DAS and 45 DAS in the respective treatments.

Groundnut-VRI 8

It is a derivative from the cross ALR 3 x AK 303. The crop duration is 105 - 110 days. The average yield was 2130 kg ha^{-1} in rainfed and 2700 kg ha^{-1} in irrigated conditions. The growth habit of groundnut is bunch type and seed color is rose. It has high shelling percentage (70%) and oil content (48%). Pods are bold type used for table purpose (CPG 2021) [29].

Results and Discussion

Water stress mitigation effect on Leaf Area Index (LAI)

Like any other plant, groundnut leaf plays an indispensable role in photosynthesis of the plants. Foliar application of KCl has an enabling role to play in plant leaves withholding, to an extent, deficit irrigation-induced stress on the chloroplast, photosynthetic CO_2 fixation (Cakmak 2005) [4] and leaf potassium content (Umar *et al.*, 1999) [26] and (Restrepo-Diaz *et al.*, 2009) [18] onto maintaining turgor pressure in leaf (Hawkesford *et al.*, 2012) [13], thereby resulting in higher concentrations of osmotic a contributing to increase both palisade cell diameters and size of fully expanded leaves (Battie-Laclau *et al.*, 2013) [2]. Deficit irrigation-induced water stress affected adversely the leaves of the plant in terms of leaf area index as presented in Table 1.

Table 1: Water stress mitigation effect on LAI of Groundnut

Treatment	Leaf Area Index		
	45 DAS	**60 DAS**	**75 DAS**
T_1 -100% ET_c	1.96	2.82	3.66
T_2 - 75% ET_c	1.80	2.65	3.55
T_3 - 50% ET_c	1.14	1.61	2.12
T_4 - T_1 + 1% KCl	2.31	3.36	4.39
T_5 - T_2 + 1% KCl	2.57	3.83	5.14
T_6 - T_3 + 1% KCl	1.87	2.75	3.69
T_7 - T_1 + 1% HA	2.20	3.21	4.25
T_8 - T_2 + 1% HA	2.33	3.38	4.59
T_9 - T_3 + 1% HA	1.87	2.70	3.65
T_{10} - Control	1.43	2.06	2.82
S.E.D	0.11	0.17	0.23
CD (p=0.05)	0.24	0.36	0.48

Note: KCl - Potassium Chloride; HA - Humic Acid

Among the irrigation regime treatments, treatment T_5 (75% ET_c + 1% KCl) has recorded significantly higher leaf area index at 45 DAS (2.57), 60 DAS (3.83) and 75 DAS (5.14) followed by treatment T_4 (100% ET_c + 1% KCl) at the respective DAS (Table 1).
The increase in LAI at treatment T_5 (75% ET_c + 1% KCl) at respective 45 DAS, 60 DAS and 75 DAS registered 1.11, 1.14 and 1.17 times more than those of T_4 (100% ET_c + 1% KCl) in respective stages as against a decline of 1% in leaf area index at treatment T_2 (75% ET_c) from those respective LAI of treatment T_1 (100% ET_c) at 45 DAS, 60 DAS and 75 DAS, lending a credible evidence on the effectiveness of foliar application of KCl @ 1% as water stress mitigation in deficit irrigation with 25% saving of water (T_5).
The foliar application of humic acid (HA) @ 1% was studied to evaluate the comparative performance of KCl and HA as water stress mitigation in deficit irrigation. As discussed in the materials and methods of the present study, treatments T_9 through T_7 relate to the effectiveness of HA on deficit irrigation regimes vis-à-vis pure deficit irrigation regime treatments T_3 through T_1. The foliar application of HA @ 1% has mitigated deficit irrigation-induced water stress in treatment T_8 (75% ET_c + 1% HA) with 25% of saving in water as compared to treatment T_7 (100% ET_c + 1% HA). While Juxtaposing foliar application of KCl @ 1% level and HA @ 1% level on deficit irrigation regimes, it was found that KCl had quick cum more (smart) response than HA in mitigating water stress in leaves induced by deficit irrigation on account of evaluating the extent of plausible water saving onto water use efficiency in groundnut.

Water stress mitigation effect on Plant Height (cm)

Plant height at all stages of crop growth is, by and large, determined by cell division and cell elongation along with fixation of chlorophyll stability, photosynthetic CO_2 fixation for which water assumes a critical limiting factor (Cakmak 2005) [4]. Foliar application of KCl and HA as a way of mitigating water stress have been studied in deficit irrigation to minimize the effects of water stress on plant height (cm) (Meena *et al.*, 2018 [17]; Afify *et al.*, 2019) [1]. The results are presented in Table 2.

Table 2: Water stress mitigation effect on plant height (cm) of groundnut

Treatment	Plant height (cm)			
	45 DAS	60 DAS	75 DAS	Harvest
T_1 - 100% ET_c	20.66	27.55	38.11	43.52
T_2 - 75% ET_c	18.80	25.62	35.82	40.04
T_3 - 50% ET_c	12.40	17.08	24.01	26.55
T_4 - T_1 + 1% KCl	24.38	33.06	46.49	52.66
T_5 - T_2 + 1% KCl	27.55	38.02	54.40	61.08
T_6 - T_3 + 1% KCl	19.99	27.44	39.05	43.71
T_7 - T_1 + 1% HA	22.93	31.13	43.44	49.18
T_8 - T_2 + 1% HA	23.85	33.00	46.48	52.42
T_9 - T_3 + 1% HA	19.49	26.77	37.36	42.78
T_{10} - Control	16.11	22.04	30.49	36.12
S.E.D	1.14	1.57	2.27	2.53
CD (p = 0.05)	2.39	3.29	4.76	5.30

Note: KCl - Potassium Chloride; HA - Humic Acid

It was observed that treatment T_2 (75% ET_c) affected on an average plant height by 8% whereas treatment T_3 (50% ET_c) reduced the plant height by 38.4% over full irrigation treatment T_1 (100% ET_c) indicating that there was a marginal reduction in plant height with 25% of saving in irrigation water (Table 2).

When KCl was applied @ 1% through foliar application, plant height was found to increase, on the average across different stages of crop growth, at the order of 18% in treatment T_4 (100% ET_c + 1% KCl) over treatment T_1 (100% ET_c) highlighting a significant quantum of KCl effect. Similarly, the foliar application of humic acid (HA) @ 1% recorded an increase of 13% in plant height in treatment T_7 (100% ET_c + 1% HA) as compared to treatment T_1 (100% ET_c).

Water stress mitigation was studied in deficit irrigation regimes in groundnut by examining treatments T_9 through T_4. With regard to the effectiveness of KCl as a means of mitigating water stress induced through deficit irrigation, it was found that plant height registered an increase of 15% in treatment T_5 (75% ET_c + 1% KCl) but recorded a decline at the order 16.8% in treatment T_6 (50% ET_c + 1% KCl) over treatment T_4 (100% ET_c + 1% KCl), clearly pointing out treatment T_5 as optimal deficit irrigation regime with 25% saving in irrigation water. On the other hand, Table 2 revealed that plant height increased at the rate of 6% in treatment T_8 (75% ET_c + 1% HA) but registered adversely a drop by 13.8% in treatment T_9 (50% ET_c + 1% HA) over treatment T_7 (100% ET_c + 1% HA).

Water stress mitigation in Dry Matter Production (kg ha^{-1})

Dry matter production is more susceptible to irrigation water and it gets instantaneously affected due to water stress induced by deficit irrigation. Water stress mitigation has become inevitable in evolving optimal deficit irrigation regimes with a view to save water and increase its use efficiency. Studies pertaining to dry matter accumulation emphasized that foliar application of KCl increased dry matter production through increasing the leaf potassium concentration as well as activating photosynthesis and its attributes (K^+) (Beringer and Nothdurft 1985 [3]; Makhdum *et al.*, 2007 [15]; Restrepo-Diaz *et al.*, 2009 [18]; Kundu *et al.*, 2021) [14]. In line with these recent studies emphasizing KCl as a medium to mitigate water stress was taken up here to assess the extent of restoring K through foliar application of KCl. Besides, the effectiveness of KCl @ 1% was also evaluated by comparing with foliar application of humic acid (HA) @ 1%. The results are presented in Table 3.

Table 3: Water stress mitigation effect on DMP (kg ha^{-1}) of Groundnut

Treatments	Dry Matter Production (kg ha^{-1})			
	45 DAS	60 DAS	75 DAS	Harvest
T_1 - 100% ET_c	1330	2233	3767	5867
T_2 - 75% ET_c	1184	2032	3503	5456
T_3 - 50% ET_c	811	1384	2373	3696
T_4 - T_1 + 1% KCl	1583	2680	4596	7099
T_5 - T_2 + 1% KCl	1820	3135	5423	8448
T_6 - T_3 + 1% KCl	1298	2224	3860	5892
T_7 - T_1 + 1% HA	1529	2590	4445	6864
T_8 - T_2 + 1% HA	1652	2823	4889	7551
T_9 - T_3 + 1% HA	1331	2279	3956	5972
T_{10} - Control	1037	1742	2976	4517
S.E.D	78.75	135.85	236.77	369.81
CD (p = 0.05)	165.45	285.42	497.45	776.97

Note: KCl - Potassium Chloride; HA - Humic Acid

From the above Table (3) revealed that higher dry matter production was recorded from T_5 (75% ET_c + 1% KCl) at 45 DAS (1820 kg ha^{-1}), 60 DAS (3135 kg ha^{-1}), 75 DAS (5423 kg ha^{-1}) and at harvest (8448 kg ha^{-1}) followed by T_4 (100% ET_c + 1% KCl). When imposed deficit irrigation regimes through drip irrigation, treatment T_2 (75% ET_c) registered a marginal decline of 7.7% in dry matter production with 25% of saving in irrigation water over full irrigation treatment T_1 (100% ET_c) whereas treatment T_3 (50% ET_c) was found to have a drastic decline of 37.4% in dry matter production as compared to full irrigation treatment T_1 (100% ET_c).

On evaluating the effectiveness of KCl applied @ 1% through foliar application, dry matter production registered, on the average, an increase of 20.9% in treatment T_4 (100% ET_c + 1% KCl) vis-à-vis treatment T_1 (100% ET_c) whereas effectiveness of humic acid (HA) @ 1% foliar application was found to have an increase of 16.9% in dry matter production over the treatment T_1 (100% ET_c).

As discussed earlier, an attempt was made to assess what extent water stress mitigating agents namely KCl and HA played their part in managing water stress arising out of deficit irrigation regimes with an intent of saving water and maximizing water use efficiency through dry matter production. It was observed that dry matter production (DMP) recorded an increase of 18% in treatment T_5 (75% ET_c + 1% KCl) but registered a significant reduction at the order 16.8% in treatment T_6 (50% ET_c + 1% KCl) over treatment T_4 (100% ET_c + 1% KCl), validating treatment T_5 as optimal deficit irrigation regime with 25% saving in irrigation water. On the other hand, Table 3 showed that DMP increased at the rate of 9.6% in treatment T_8 (75% ET_c + 1% HA) but recorded a perceptible decline by 12.3% in treatment T_9 (50% ET_c + 1% HA) over treatment T_7 (100% ET_c + 1% HA).

Conclusion

This study has brought out some insights into the water stress mitigation dynamics in developing an optimal deficit irrigation regime in groundnut-VRI 8 variety. It made use of Randomized Block Design to examine the effectiveness of KCl and Humic Acid (HA) in mitigating water stress arising out of deficit irrigation regimes. This study confines itself to comprehend growth attributes namely leaf area index (LAI), plant height and dry matter production (DMP) and identify an optimal deficit irrigation regime. The experimental study has demonstrated that KCl has emerged as smart water stress mitigating agent with an appreciable quantum of saving in irrigation water and its use efficiency in identifying an optimal deficit irrigation regime T_5 (75% ET_c + 1% KCl) though outperformed its counterpart of humic acid (HA).

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