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Foliar application of urea and potassium chloride minimizes terminal moisture stress in lentil (*Lens culinaris* L.) crop

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ABSTRACT

Soil moisture stress in lentil (*Lens culinaris* L.) cultivated in rice (*Oryza sativa* L.) fallows of Tripura (50 m above msl), India, is one of the issues related to low productivity. Effects of foliar feeding of lentil with urea and potassium chloride KCl @ 2% each, singly or in combination either at 50% flowering, 50% podding or both at 50% flowering + 50% pod formation stages under moisture stress condition were investigated. The key physiological parameters *viz*. chlorophyll *a*, chlorophyll *b*, total chlorophyll content, leaf relative water content (LRWC), excised leaf water loss (ELWL) and yield attributes of lentil were measured. There were significant ($p < 0.05$) increases in chlorophyll *a*, chlorophyll *b* and total chlorophyll content at 50% flowering and 50% pod formation stage in plants treated either with 2% KCl alone or in combination with 2% urea as compared to those under control and 2% urea alone. Further, LRWC and ELWL were the highest (83%) and lowest (0.7%) under combined application of two agro chemicals, respectively. Significant ($p < 0.05$) increases in plant height, number of branches per plant, numbers of pods per plant and biomass as well as seed yield were also observed with combined foliar application of agrochemicals in comparison to those under control. The highest LRWC and lowest ELWL were recorded in case of foliar spray at 50% flowering + 50% pod formation as compared to either 50% flowering or 50% pod formation stage alone. Foliar application of both agro-chemicals mitigates the terminal moisture stresses especially in underutilized rice-fallow lands for successful cultivation of *rabi* crops like lentil.

Key words: Chlorophyll, Foliar nutrition, Lentil, LRWC, Rice fallow land, Seed yield.

INTRODUCTION

India is a global leader in rice (*Oryza sativa* L.) production with ~ 44.6 million hectare (mha) area under rice cultivation, of which ~ 11.7 mha remains fallow during the *rabi* season (October - March), soon after harvest of *kharif* rice. Uttar Pradesh, Bihar, Chhattisgarh, Jharkhand and Madhya Pradesh constitute ~82% of these fallow lands (Yadav *et al.,* 2015; Yadav *et al*., 2017). Such fallow lands during winter or post rainy-season with diverse pedo- and agro-climatic conditions are potential niches to grow short cycle pulses. The residual soil moisture at rice harvest may be used to raise a short-season pulse crops with adequate agronomic and conservation measures. Cultivation of a short duration and high yielding varieties of rice may vacate fields early in September-October, allowing cultivation of a succeeding pulse crop. Lentil (*Lens culinaris* L.) is one such important *rabi* pulse crops and prominent source of vegetable protein grown mainly on residual soil moisture (Yadav *et al*., 2015). It grows well in most rice fallow areas, however; productivity is often low due to insufficient nutrient assimilation under terminal moisture stress. Hence, identifying possible strategies to overcome the terminal moisture stress in rice fallow for lentil cultivation necessitates knowledge of the specific foliar nutrient management practices.

Similar to other parts of India, the North-Eastern region also has a large area as rice fallow land after the *Kharif* season rice (Das *et al.,* 2012). Hence, there exists a great potential for expansion of area under pulse crops including lentil (Yadav *et al.,* 2017). However, the average seed yield of lentil in the region is low compared with its potential yields due to lack of adequate short duration varieties, terminal moisture and heat stress, improper nutrient management and soil acidity. In Tripura more than 60,000 ha of land remains as fallow land after harvest of *Aman* (*kharif)* rice. So, there are possibilities of inclusion of lentil as second crop through adoption of improved management practices and varieties to enhance farm income. As a part of nutrient management initiative, urea is one of the most important nitrogenous fertilizers used in agricultural fields. Additionally, potassium is required for numerous plant processes like

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enzyme activation, stomatal activity and photosynthesis and ultimately for better crop yield. There are established evidences of mitigating soil moisture stress through application of agro-chemicals (urea, potassium chloride, boron *etc.*) in *rabi* crops like urdbean (*Vigna mungo* L.) (Math *et al*., 2014). However, information on foliar nutrition of lentil crop in situ moisture stress condition is lacking. Considering the opportunity of sustainable resource utilization of the rice fallows, an attempt was made in a field experiment during *rabi* season (year: 2017-18) to elucidate the efficacy of two common agro-chemicals *i.e.*, urea and KCl for minimizing the negative impacts of soil moisture stress on lentil crop.

MATERIALS AND METHODS

Experimental site and conditions

A field experiment was conducted at the Research Farm facilities of ICAR Research Complex for North Eastern Hill (NEH) Region, Tripura Centre, Lembucherra, Tripura (W), India, during winter seasons in the year 2017-18. The annual rainfall of the study site was 2200 mm. The soil of the experimental site was sandy loam type, acidic in reaction [pH (1.25-5.2)] and the baseline soil sample had 5.6 g kg^{-1} soil organic carbon (SOC), 251.1 kg ha^{-1} available nitrogen (N), 20.2 kg ha^{-1} available phosphorus (P) and 170.1 kg ha^{-1} available potassium (K).

Experimental design and crop management

The experiment trial was designed to test three levels of foliar spray of agro-chemicals (Urea and KCl) @ 2% either individually or in combination at three distinct application stages *viz*. 1) 50% flowering, 2) 50% podding and 3) at both 50% flowering + 50% podding compared to a control (no spray). The experiment was laid out in a factorial completely randomized block design with three replications. Lentil var. Tripura Selection 1 was sown at 25 cm spacing under reduced tillage, two time power tilling only, condition in a gross plot size of 9.8 m × 2.3 m. A starter dose of 20 kg ha^{-1} N, 27 kg ha^{-1} P and 33 kg ha^{-1} K were applied in furrows before sowing the seeds. The crop was raised with residual soil moisture and lifesaving irrigation was provided at the flowering stage for better growth.

Chlorophyll content

Leaf chlorophyll content was estimated by the method of Arnon (1949). Fresh leaf sample was finely cut and mixed well; 1 g of tissue was weighed and homogenized with the addition of 20 ml of 80 % acetone. The solution was centrifuged at 5000 r.p.m for 5 minutes and the supernatant was made upto 100 ml with 80 % acetone. The absorbance of the supernatant was recorded at 645 and 663 nm against the solvent (80 % acetone) blank. Chlorophyll content in the extract was calculated using the formulae:

Chl *a* (mg g^{-1} fw) = 12.7 (A_{663}) - 2.69 (A_{645}) ×V/1000×W
Chl *b* (mg g^{-1} fw) = 22.9 (A_{645}) – 4.68 (A_{663}) ×V/1000×W
Total Chl (mg g^{-1} fw) = 20.2 (A_{645}) + 8.02 (A_{663}) ×V/1000×W

Where,
A = Absorbance at specific wavelength.
V = Final volume of chlorophyll extract in 80 % acetone.
W = Fresh weight of tissue extracted.

Leaf relative water content (LRWC)

Data related to Leaf relative water content (LRWC) was recorded at 50% flowering and 50% pod formation stages separately. The third leaves from top (fully expanded youngest leaf) of two plants from each treatment were used to determine the LRWC. Immediately after sampling, leaves were sealed within a plastic bag and processed in the laboratory. Fresh weight (FW) was determined within two hours after leaves excision. Then turgid weight (TW) was obtained after soaking leaves in distilled water for 16-18 hr at room temperature. After soaking, leaves were blotted dry using tissue paper to calculate the TW. The samples were dried in an oven for about 72 hours at 65°C and measured to a constant weight. LRWC was calculated using the formula given by Lazcano-Ferrat and Lovatt (1999):

Leaf relative water contents (%) =
$$(FW-DW) / (TW-DW) \times 100\%$$

Excised leaf water loss (ELWL)

Data for ELWL was recorded at both flowering and podding stages separately. The third leaf from top (fully expanded youngest leaf) of two plants for each treatment was used to determine ELWL. The leaves were placed in polythene bags and transported to the laboratory as quickly as possible in order to minimize water losses by evaporation. The leaves were weighed at three stages, immediately after sampling (fresh weight: FW), after placing at room temperature for 6 h (wilted weight: WW) and after drying in an oven for 24 h at 65°C and (dry weight: DW). ELWL was calculated by using formula given by Clarke (1987):

$$ELWL (\%) = \{(FW - WW) / DW \%\}$$

Plant sampling and yield measurement

The growth parameters (plant height, primary and secondary branches), yield attributes (pods/plant and seeds/pod) and seed yield of lentil were recorded at harvest. Number of pods were taken by counting the total number of pods of five tagged plants in each plot and then averaged was calculated. Number of seeds were taken by counting the total number of seed per pod of each of five tagged plants and then averaged was recorded. For biological yield, 4 square meter crop area was harvested from each plot. Then, crops were sun dried and biological yield was converted into kg per hectare. From 4 square meter crop area, seed yield was obtained and expressed into kg per hectare. The yield of lentil was estimated from the weight of sun-dried seeds (12% moisture content) obtained from each plot after threshing and cleaning.

Statistical analysis

The experimental data pertaining to each parameter of the study were subjected to statistical analysis by using the

technique of analysis of variance and their significance was tested by "F" test (Gomez and Gomez, 1984). The standard error of means (SEm+) and least significant difference (LSD) at 5% probability were worked out to evaluate the differences between treatment means for each parameter studied.

RESULTS AND DISCUSSION

A significant effect ($p<0.05$) of foliar spray application of agro-chemical on the measured physiological parameters *viz*. chlorophyll *a*, chlorophyll b and total chlorophyll content, relative water content and excised leaf water loss (ELWL) and yield, as well yield attributes was observed in the present study (Table 1, 2). Compared to the control, significant ($p<0.05$) increases in chlorophyll a, chlorophyll b and total chlorophyll content were noticed in leaves of lentil plant received either singular or combined application of 2% urea and 2% KCl suggesting the potential of agrochemicals in reducing the extent of chlorophyll loss under low moisture. In the present study, significant increase ($p <0.05$) in mean values of chlorophyll *a* (6.7 µg g^{-1} fw, 10.3 µg g^{-1} fw), chlorophyll *b* (5.74 µg g^{-1}fw, 2.94 µg g^{-1}fw) and total chlorophyll content (12.44 µg g^{-1} fw , 13.24 µg g^{-1} fw) at 50% flowering and 50% podding, respectively, were observed in leaves of treated plants either 2% KCl alone or in combination with 2% urea as compared to control and 2% urea. Earlier reports are also indicative of an efficient nutrient uptake and utilization under soil moisture stress in crops through application of nitrogen and potassium fertilizer (Waraich *et al*., 2011; Ge *et al*., 2012). Additional supply of key nutrients as either 2% KCl alone or in combination with 2% urea might have played an ameliorative function in this study. Interestingly, the effect was more pronounced in case

Table 1: Effect of agro-chemicals and time of foliar application on chlorophyll content in lentil.

Treatment	75 DAS			90 DAS		
	Chlorophyll a (µg g^{-1} fw)	Chlorophyll b (µg g^{-1} fw)	Total chlorophyll (µg g^{-1} fw)	Chlorophyll a (µg g^{-1} fw)	Chlorophyll b (µg g^{-1} fw)	Total chlorophyll (µg g^{-1} fw)
Agro-chemical concentration						
Control	4.7	2.22	6.92	6.7	2.32	9.02
2% Urea	6.1	4.06	10.16	9.2	2.79	11.99
2% KCl	6.5	4.83	11.33	9.8	2.89	12.69
2% Urea + 2% KCl	6.7	5.74	12.44	10.3	2.94	13.24
SEm±	0.43	0.58	1.05	0.80	0.12	0.96
$LSD_{0.05}$	1.30	1.74	3.14	2.40	0.37	2.87
Time of foliar spray						
50% Flowering	6.3	4.72	11.02	9.4	2.87	12.27
50% Podding	5.9	3.76	9.66	9.0	2.77	11.77
50% Flowering+ 50% podding	7.1	6.16	13.26	10.8	2.97	13.77
SEm±	0.10	0.29	0.42	0.10	0.01	0.13
$LSD_{0.05}$	0.30	0.86	1.26	0.30	0.03	0.40

Table 2: Effect of agro-chemicals and time of foliar application on yield attributes and yield of lentil.

Treatment	Plant height (cm)	Number of branches/ plant	Number of pods/ plant	Number of seeds/ pod	Biomass yield (kg/ha)	Seed yield (kg/ha)	Harvest index
Agro-chemical concentration							
Control	31.8	7.7	33.9	2.0	1042	396	0.28
2% Urea	37.4	9.1	55.8	2.0	2013	793	0.30
2% KCl	38.5	9.5	60.6	1.8	2377	964	0.31
2% Urea + 2% KCl	37.7	10.5	68.2	2.0	2439	995	0.30
SEm±	0.56	0.42	2.07	0.02	59.53	31.31	0.01
$LSD_{0.05}$	1.67	1.26	6.16	0.06	176.88	93.03	0.03
Time of foliar spray							
50% Flowering	38.2	8.9	59.8	1.9	1978	843	0.30
50% Podding	35.2	8.0	49.8	1.9	1233	678	0.35
50% Flowering+ 50% podding	40.1	12.2	74.9	2.0	3617	1231	0.25
SEm±	0.49	0.37	1.79	0.02	51.56	27.12	0.01
$LSD_{0.05}$	1.45	1.09	5.33	0.05	153.18	80.57	0.03

of 2% KCl compared 2% urea, indicating its effectiveness in managing soil moisture stress. Further, 2% KCl had no significant difference ($p < 0.05$) with its combined application, suggesting that KCl application singularly will be an economically viable option in effectively controlling such stressor. Nitrogen supplied through urea contributes to the structural organization of chlorophyll, whereas potassium in KCl functions as an activator or coenzyme in chlorophyll biosynthesis (Abdel Mohatgally, 2014). Foliar application has already been proven as an effective means for improving nutrient uptake as well as its utilization (Fageria *et al*., 2009). Thus, foliar nutrition with either KCl or urea alone or in combination might have potentiated nutrient balance in our study, thereby, minimizing the stress effect. Decline in chemical activity of water and a loss of turgor in plant cells is often encountered as a result of drought induced osmotic stress (Zhang *et al*., 2013; Yıldıztugay *et al*., 2014). These changes, may further lead to impairment of nitrate assimilation due to reduced activity of nitrate reductase (NRA) enzyme (Zhang *et al*., 2009). These, ultimately leads to reduction in plant growth and/or plant death as well as reduced LRWC, which is being recognized as an effective indicator of plant water status (Zhang *et al*., 2009). In this study, LRWC and ELWL were found to be the highest (83%) and the lowest (0.7%), respectively (Fig 1 and 3), in case of combined application as compared to other two treatments, although the values were comparable and statistically non-significant between 2% KCl alone or in combination with 2% urea. This observation indicates the effectiveness of the used agrochemicals in improving the water status of lentil crop. Positive response to several agro-chemicals are also reported in crops like oilseeds (Fanaei *et al*., 2009), mung bean (Nandwal *et al*., 1998), maize (Premachandra *et al*., 1991) and wheat (Pier and Berkowitz, 1987) under drought stress. We further observed higher LRWC under soil moisture deficit conditions using KCl application than the control (Fig 1). It is known that application of K contributes to improved cell turgor through osmotic adjustment (Maathuis and Sanders, 1996). Improvement in relative water contents, cell membrane stability, water use efficiency, leaf area index, chlorophyll contents, grain protein contents, plant height, number of primary branches, number of secondary branches, pods per plant, grains yield were also reported in legumes (Namvar *et al*., 2013) through application of urea.

Drought stress causes drastic reduction in leaf chlorophyll content, affecting the photosynthetic efficiency of plants, reducing dry matter accumulation and poor grain yield (Wang *et al*., 2018). In this study, a significant increase ($p < 0.05$) in plant height, number of branches per plant, number of pods per plant and biomass as well as seed yield with agrochemical application as compared to control was observed. This might be related to enhanced chlorophyll content on account of foliar application of the agrochemical; thus, enabling higher photosynthesis under stress conditions (Arabzadeh, 2013). Remarkable increase in plant height (37.7 cm), number of branches per plant (10.5), number of

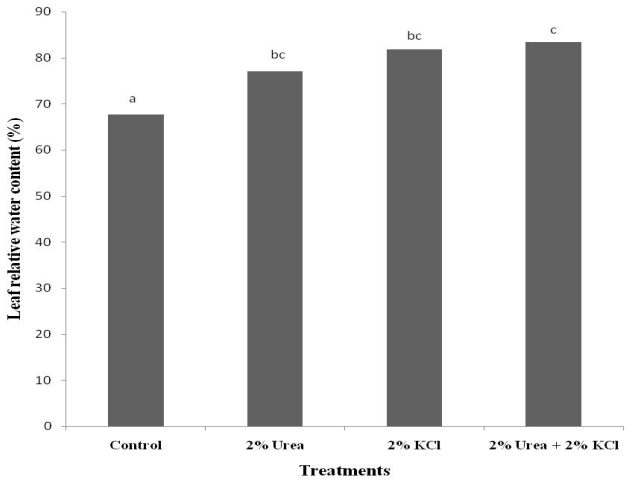

Fig 1: Graph presenting the treatment effect of agrochemicals on leaf relative water content in lentil.

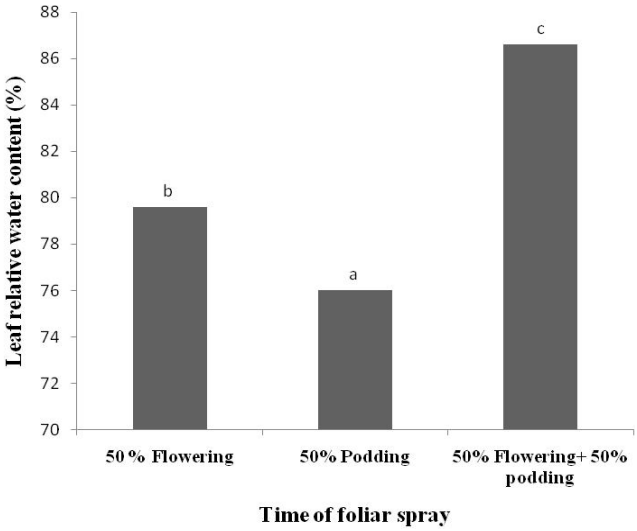

Fig 2: Graph presenting the treatment effect of time of foliar spray on leaf relative water content in lentil.

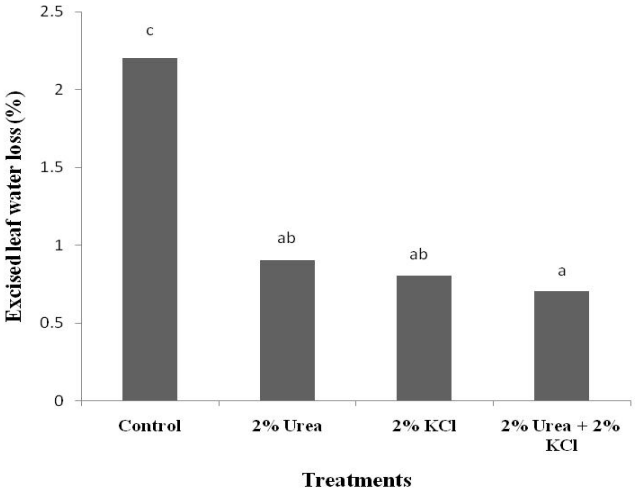

Fig 3: Graph presenting the treatment effect of agrochemicals on excised leaf water loss in lentil.

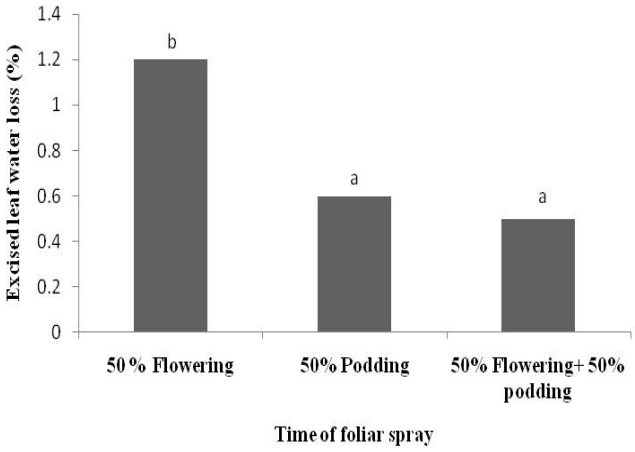

Fig 4: Graph presenting the treatment effect of time of foliar spray on excised leaf water loss in lentil.

pods per plant (68.2), biomass yield (2439 kg ha^{-1}) and seed yield (995 kg ha^{-1}) were observed through combined application, followed by singular application of 2% KCl and 2% urea (Table 2). This was in agreement with many earlier studies in chickpea (Parimala *et al*., 2013), mungbean (Beg and Ahmad, 2012, Majeed *et al*., 2016), lentil (Nagraju, 2017) and cowpea (Choudhary and Yadav, 2011), wherein foliar application of KCl reportedly enhanced growth characteristics and seed yield. This may be attributed to the role of potassium in drought adaptations (Sardans *et al*., 2012, Grzebisz *et al*., 2013) linked to various biological processes such as cell osmoregulation, which helps in maintaining the cell turgor and expansion required for promoting root and shoot growth and regulate stomatal opening, thereby optimizing water-use efficiency (Egilla *et al*., 2005; Kanai *et al*., 2011, Majeed *et al*., 2016). Besides, potassium helps in maintaining the inner membrane of chloroplast and proton gradient of thylakoid membranes, which promote photosynthetic phosphorylation which is essential for sustaining photosynthesis during stressful condition, leading to higher dry matter production and seed yield (Hermans *et al*., 2006; Yurtseven *et al*., 2005). Drought mitigation through foliar application of urea is reported in various crops (Asadullah *et al*., 2017; Gou *et al*., 2017). Nutrient uptake is highly reduced under water stress condition; therefore, drought imposed nutrient deficiency becomes severe during terminal growth stages (Gunes *et al*., 2006). Foliar application of nitrogen fertilizer, supplemented the nitrogen uptake deficiency which resulted the improvement of lentil yield performance under limited availability. This is due to the fact that nitrogen is vitally involved in various physiological processes such as protein biosynthesis, nucleic acid linked processes, protoplast formation, chlorophyll synthesis, leaf area, cell size and photosynthetic activity (Dordas and Sioulas, 2008; Waraich *et al*., 2011). Except for number of pods per plant and number of seeds per pod as well, no difference ($p < 0.05$) was observed between yield attributes and yield w.r.t 2% KCl and combined application of 2% urea + 2% KCl.

Time of foliar spray application significantly affected the chlorophyll content, leaf relative water content and excised leaf water loss (Fig 2 and 4). It was observed that foliar spray at both 50% flowering + 50% podding stage exhibited better response than either at 50% flowering or at 50% podding stage. The highest chlorophyll a, chlorophyll b and total chlorophyll content were recorded at 75 days after sowing: DAS (7.1 µg g^{-1} fw, 6.16 µg g^{-1} fw and 13.26 µg g^{-1} fw). Similarly, at 90 DAS, maximum treatment response was observed at both 50% flowering + 50% podding with highest chlorophyll *a* (10.8 µg g^{-1} fw), chlorophyll *b* (2.97 µg g^{-1} fw) and total chlorophyll content (13.77 µg g^{-1} fw). The highest LRWC and the lowest ELWL were recorded with a percentage value of 86% and 0.5%, respectively, in case of foliar spray at both 50% flowering + 50% podding as compared to application of foliar spray at flowering and podding alone. Timing of foliar application also significantly affects the yield attributes and yield of lentil. Foliar spray at both 50% flowering + 50% podding resulted a maximum increase in plant height (40.1 cm), number of branches per plant (12.2), number of pods per plant (74.9), number of seeds per pod (2), biomass yield (3617 kg ha^{-1}) and seed yield (1231 kg ha^{-1}) followed by application at both 50% flowering + 50% podding stage. Our result corresponds the findings of Palta *et al*. (2005) and Zeidan (2003) wherein foliar application of urea at 50% flowering resulted in increase of yield and seed protein. Foliar spray of nitrogen has been found to delay leaf senescence and improves yield (Das and Jana, 2015). Foliar application of nutrients at flowering and podding stage allows adequate nutrient supplementation essential for enhancing the number of floral buds and preventing floral shedding by maintaining optimum bio-physiological conditions in plants (Maheswari and Karthik, 2017).

CONCLUSION

Foliar application of common agro-chemicals to lentil crop proved to have vast potential in bringing the underutilized rice-fallow lands elsewhere for successful cultivation of *rabi* crops by physiologically mitigating the repercussions of terminal moisture stresses on crops. Besides, the foliar spray of 2% KCl at both 50% flowering + 50% podding stages of lentil crop was found to be effective in sustaining the seed yield under rice-fallow condition.

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REFERENCES

Abdel-Motagally, F.M.F. (2014). Response of lentil to foliar application of potassium phosphate under different irrigation. Assiut J. Agric. Sci. 45: 28-38.

Arabzadeh, N. (2013). The impact of drought stress on photosynthetic quantum yield in *Haloxylon aphyllum* and *Haloxylon persicum*. African J. Plant Sci. 7: 185-189.

Arnon, D.I. (1949). Copper enzymes in isolated chloroplasts, polyphenoxidase in *Beta vulgaris*. Plant Physiol. 24: 1-15.

Asadullah, M., Amir, M.M., Akhtar, M.A., Anwar, M.N. (2017). Mitigation of drought effects by nitrogen foliar spray in chickpea (*Cicer arietinum* L.). J. Agric. Basic Sci. 2: 2518-4210.

Beg, M. Z. and Ahmad, S. (2012). Effect of potassium on mungbean. Indian J. Life Sci. 1: 109-114.

Choudhary, G.L. and Yadav, L.R. (2011). Effect of fertility levels and foliar nutrition on cowpea productivity. J. Food Legumes. 24: 67-68.

Clarke, J.M., (1987). Use of Physiological and Morphological Traits in Breeding Programmes to Improve Drought Resistance of Cereals. In: Drought Tolerance in Winter Cereals, [Srivastava J.P., Porcedo E., Acevedo E. and Varma S. (Eds.)], John Wiley and Sons, New York. pp 171–190.

Das, A., Ramkrushna, G.I., Patel, D.P., Choudhury, B.U., Munda, G.C., Rajkhowa, D.J., Ngachan, S.V. (2012). Zero tillage pea, lentil and toria cultivation in rice fallow for diversification and resource conservation in hills. ICAR-Research Complex for NEH Region, Umiam-793103, Meghalaya.

Das, S.K. and Jana, K. (2015). Effect of foliar spray of water soluble fertilizer at pre flowering stage on yield of pulses. Agric. Sci. Digest. 35: 275-279.

Dordas, C.A. and Sioulas C. (2008). Safflower yield, chlorophyll content, photosynthesis and water use efficiency response to nitrogen fertilization under rainfed conditions. Ind. Crops Prod. 27: 75-85.

Egilla, J.N., Davies, F.T., Boutton, T.W. (2005). Drought stress influences leaf water content, photosynthesis and water-use efficiency of Hibiscus rosa-sinensis at three potassium concentrations. Photosynthetica. 43: 135-140.

Fageria, N.K., Barbosa Filho M.P., Moreira, A. and Guimaraes, C.M. (2009). Foliar fertilization of crop plants. J. Plant Nutr. 32: 1044-1064.

Fanaei, H.R., Galavi, M., Kafi, M., Ghanbari Bonjar, A. (2009). Amelioration of water stress by potassium fertilizer in two oilseed species. Int. J. Plant Prod. 3: 41-54.

Ge, T.D., Sun, N.B., Bai, L.P., Tong, C.L., Sui F.G. (2012). Effects of drought stress on phosphorus and potassium uptake dynamics in summer maize (*Zea mays*) throughout the growth cycle. Acta Physiol. Plant. 34: 2179-2186.

Gomez, K.A. and Gomez A.A., (1984). Statistical Procedures for Agricultural Research (2nd Ed.). John Wiley and Sons, New York, 680p.

Gou, W., Zheng, P., Tian, L., Gao, M., Zhang, L., Akram, N.A., Ashraf, M. (2017). Exogenous application of urea and a urease inhibitor improves drought stress tolerance in maize (*Zea mays* L.). J. Plant Res. 130: 599-609.

Grzebisz, W., Gransee, A., Szczepaniak, W., Diatta, J. (2013). The effects of potassium fertilization on water-use efficiency in crop plants. J. Plant Nutr. Soil Sci.176: 355-374.

Gunes, A., Cicek, N., Ina, A., Alpaslan, M., Eraslan, F., Guneri, E., Guzelordu, T. (2006). Genotypic response of chickpea (*Cicer arietinum* L.) cultivars to drought stress implemented at pre and post-anthesis stages and its relations with nutrient uptake and efficiency. Plant Soil Environ. 52: 368-376.

Hermans, C., Hammond, J.P., White, P.J., Verbruggen, N. (2006). How do plants respond to nutrient shortage by biomass allocation? Trends Plant Sci. 11: 610-617.

Kanai, S., Moghaieb, R.E., El-Shemy, H.A., Panigrahi, R., Mohapatra, P.K., Ito, J., Nguyen, N.T., Saneoka, H., Fujita, K. (2011). Potassium deficiency affects water status and photosynthetic rate of the vegetative sink in green house tomato prior to its effects on source activity. Plant Sci. 180: 368-374.

Lazcano-Ferrat, I. and Lovatt, C. (1999). Relationship between relative water content, nitrogen pools and growth of *Phaseolus vulgaris* L. and *P. acutifolius* A. Gray during water deficit. Crop Sci. 39: 467-475.

Maathuis, F.J.M., Sanders, D. (1996). Mechanisms of potassium absorption by higher plant roots. Physiol. Plant. 96: 158-168.

Maheswari, U.M., Karthik, A. (2017). Effect of foliar nutrition on growth, yield attributes and seed yield of pulse crops. Adv. Crop Sci. Tech. 5: 278.

Majeed, S., Muhammad, A., Muhammad, L., Muhammad, I. and Hussain, M. (2016). Mitigation of drought stress by foliar application of salicylic acid and potassium in mungbean (*Vigna radiata* L.). Legume Res. 39: 208-214.

Math, G., Vijayakumar, A.G., Hegde, Y. and Kumari, B. (2014). Study of different moisture stress mitigation techniques for *rabi* urdbean [*Vigna mungo* (L.) Hepper]. Indian J. Dryland Agric. Res. and Dev. 29: 45-48.

Nagraju, M. (2017). Drought management through foliar application and balance supply of nutrients in lentil. M. Sc. Thesis. Banaras Hindu University http://Krishikosh.egranth.ac.in/handler/1/5810074023.

Namvar, A., Sharifi, R.S., Khandan, T. and Moghadam, M.J. (2013). Seed inoculation and inorganic nitrogen fertilization effects on some physiological and agronomical traits of chickpea (*Cicer arietinum* L.) in irrigated condition. J. Cent. Euro. Agric. 14: 28-40.

Nandwal, A.S., Hooda, A., Datta, D. (1998). Effect of substrate moisture and potassium on water relations and C, N and K distribution in *Vigna radiata*. Biol. Plant. 41: 149-153.

Palta, J.A., Nandwal, A.S., Kumari, S. and Turner, N.C. (2005). Foliar nitrogen applications increase the seed yield and protein content in chickpea (*Cicer arietinum* L.) subject to terminal drought. Aust. J. Agric. Res. 56: 105-112.

Parimala, K., Muendel, H.H., Chaudary, M.F. (2013). Effect of nutrient sprays on yield and seedling quality parameters of chickpea (*Cicer arietinum* L.). Pl. Arch. 13: 735-737.

Pier, P.A., Berkowitz, G.A. (1987). Modulation of water stress effects on photosynthesis by altered leaf K+. Plant Physiol. 85: 655-661.

Premachandra, G.S., Saneoka, H., Ogata, S. (1991). Cell membrane stability and leaf water relations as affected by potassium nutrition of water-stressed maize. J. Exp. Bot. 42: 739-745.

Sardans, J., Peñuelas, J., Coll, M., Vayreda, J., Rivas-Ubach, A. (2012). Stoichiometry of potassium is largely determined by water availability and growth in Catalonian forests. Funct. Ecol. 26: 1077-089.

Wang, W.S., Wang, C., Pan, D.Y., Zhang, Y.K., Luo, B., Ji, J.W. (2018). Effects of drought stress on photosynthesis and chlorophyll fluorescence images of soyabean (*Glycine max*) seedlings. Int. J. Agric. Biol. Eng. 11: 196-201.

Waraich, E.A., Ahmad, R., Saifullah, M.Y. A. and Ehsanullah (2011). Role of mineral nutrition in alleviation of drought stress in plants. Aust. J. Crop Sci. 5: 764-777.

Yadav, G.S., Datta, M., Saha, P. and Debbarma, C. (2015). Evaluation of lentil varieties/lines for utilization of rice fallow in Tripura. Indian J. Hill Farm. 28: 90-95.

Yadav, G.S., Lal, R., Meena, R.S., Datta, M., Babu, S., Das, A., Layek, J. and Saha, P. (2017). Energy budgeting for designing sustainable and environmentally clean/safer cropping systems for rainfed rice fallow lands in India. J. Clean. Prod. 158: 29-37.

Yıldıztugay, E., ÖzfidanKonakçı, C., Küçüködük, M., Duran, Y. (2014). Modulation of osmotic adjustment and enzymatic antioxidant profiling in *Apera intermedia* exposed to salt stress. Turk. J. Bot. 38: 99-111.

Yurtseven, E., Kesmez, G.D., U ¨ nlu¨kara, A. (2005). The effects of water salinity and potassium levels on yield, fruit quality and water consumption of a native central anatolian tomato species (*Lycopersicon esculantum*). Agric. Water Manage 78: 128-135.

Zeidan, M.S. (2003). Effect of sowing dates and urea foliar application on growth and seed yield of determinate faba bean (*Vicia faba* L.) under Egyptian conditions. Egypt J. Agron. 24: 93-102.

Zhang H., Niu X., Liu J., Xiao F., Cao S., Liu Y. (2013). RNAi-directed down regulation of vacuolar H^+-ATPase subunit a results in enhanced stomatal aperture and density in rice. PLoS ONE 8.

Zhang, L.X., Li, S.X., Liang, Z.S., Li, S.Q. (2009). Effect of foliar nitrogen application on nitrogen metabolism, water status and plant growth in two maize cultivars under short-term moderate stress. J. Plant Nutr. 32: 1861-1881.