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MANAGEMENT OF MOISTURE STRESS IN INDIAN MUSTARD (*BRASSICA JUNCEA* L.) UNDER SUB TROPICAL RAINFED CONDITIONS OF NORTH INDIA

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ABSTRACT

In a field experiment the performance of eleven treatments comprising of agrochemicals urea (1%), potassium nitrate (1%) and thiourea (0.05%) sprayed at various crop growth stages in Indian mustard was evaluated for mitigation of moisture stress at terminal stages under rainfed conditions of Jammu. The twice foliar application of 0.05% thio-urea at 50 % flowering stage followed by 50 % siliqua filing stage resulted in significant increase in seed yield (12.5 to 13.6 t ha^{-1}), oil yield (4.49 to 4.90 q ha^{-1}) and Harvest Index (25.81 to 32.41) of Indian mustard with concomitant increase in the Cumulative water use (4.57 to 5.80) and Rainfall use efficiency (5.84 to 7.16) and benefit:cost ratio (1.23 to 1.47) than other treatments in comparison during both the years of experimentation. Therefore, twice foliar application of thiourea @ 0.05 % at 50 percent flowering stage followed by 50 % siliqua filling stages was found to be the most economical treatment in mitigation of moisture stress in Indian mustard.

KEY WORDS
Thiourea
Potassium nitrate
Urea
Rainfall water use efficiency

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INTRODUCTION

Oilseed and oil are of immense importance in the country's economy as well as in the life of the people for balanced nutrition. Among the different oilseed crops, rapeseed and mustard holds a key place in Indian Agriculture (Dinda *et al*., 2015). In Jammu and Kashmir state rapeseed mustard group of crops are grown on an area of 61000 hectares with an average productivity of 803 kg ha^{-1} which is well below the national average of 1188 kg ha^{-1} from an area of 6.70 million hectares with annual production of 7.96 million tonnes (Anonymous, 2014). Rain fed areas of Jammu region constitutes dry semi-hilly belt which is rain fed in nature and is the most stressed ecosystem of this area and is locally known as *kandi* area. *Brassica campestris* var. Toria grown in Jammu region as catch crop in widely popular Maize-Toria-Wheat cropping system whereas *Brassica juncea* and *Brassica napus* are potential crop in both rainfed and irrigated conditions for domestic oil consumption purpose.

One of the major bottle neck in achieving higher productivity is that majority of the area i.e. around 70% is rain fed where moisture stress is the major limiting factor affecting the productivity of rapeseed mustard crops which is usually encountered by the crop during the vegetative as well as reproductive phases of crop growth under rain fed conditions of Jammu region.

Recent studies have indicated that low productivity of Indian mustard have been attributed to the coefficient of effectiveness and lack of efficient partitioning of photosynthates between the reproductive and vegetative parts during moisture stress conditions. Several studies in different crops have indicated that the plant growth substances have potential to enhance the productivity of crops (Sahu *et al*., 1993). The agrochemicals (urea, thiourea and potassium nitrate) can be potentially used to increase water and crop productivity as these agrochemicals can effectively improve the assimilate partitioning and yield of crops under water deficit conditions (Hayat *et al*., 2007). Henceforth, the present study was undertaken to study the effect of urea, thiourea and potassium nitrate at varying levels at different crop growth stages in Indian mustard to study its impact under semi arid subtropical condition of Jammu region.

MATERIALS AND METHODS

The field experiment was conducted during the *rabi* season of 2012-13 and 2013-14 at the Research Farm, Chatha of the Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu which is situated at 32° 40′ N latitude and 74° 58′ E longitude with an altitude of 332 m above mean sea level under rain fed conditions. The soil of the experimental field was sandy loam in texture and having 211 kg ha^{-1} alkaline permanganate oxidizable N (Subbiah and

Asija 1956), 11.7 kg ha[-1] available P (Olsen *et al.*, 1954), 118.10 kg ha[-1] 1 N ammonium acetate exchangeable K (Stanford and English 1949) and 0.38 % organic carbon (Jackson 1973). The pH of the soil was 7.1 (1:2.5 soil and water ratio). Indian mustard variety "Varuna" was sown in second fortnight of October in rows 30 cm apart during both the years using 5 kg seeds ha[-1] while maintaining plant to plant distance of 10 cm distance. Recommended dose of 60:30:15:20 kg ha[-1] of N:P:K:S was uniformly applied to all the treatments using urea, DAP and MOP as fertilizers. Full dose of Phosphorus, Sulphur and Potassium besides half dose of nitrogen was applied as basal dose at the time of sowing whereas rest of the nitrogen was given in two equal splits as top dressing at 30-35 days after sowing during both the years of experimentation. Crop was raised as per standard package and practices during both the years of experimentation. The experiment consisting of eleven treatments namely Control (T1), twice water spray at 50 % flowering followed by 50% siliqua filling stages (T2), 1% urea spray at 50 % flowering stage (T3), 1% urea spray at 50% siliqua filling stage (T4), twice foliar application of 1% urea spray both at 50% flowering followed by 50% Siliqua filling stages (T5), 0.05% thio-urea spray at 50 % flowering stage (T6), 0.05% thio-urea spray at 50% siliqua filling stage (T7), twice foliar application of 0.05% thio- urea spray both at 50% flowering followed by 50% Siliqua filling stages (T8), 1% potassium nitrate spray at 50 % flowering stage (T9), 1% Potassium nitrate spray at 50% siliqua filling stage (T10), twice foliar application of 1% Potassium nitrate spray both at 50% flowering followed by 50% Siliqua filling stage (T11) which were arranged in a randomized block design with 3 replications.

The different agrochemicals were sprayed by knapsack sprayer with flat fan T-jet nozzle using a spray volume of 700 litres ha[-1] of water at 50 % flowering as well as 50 % siliqua filling stages coinciding between 60-65 and 110-115 days after sowing (DAS). Observations on moisture status of soils at 0-25 cm soil depth and 25-50 cm soil depth at at 50 % flowering as well as 50 % siliqua filling stages were taken by using soil auger and computations were made by using soil gravimetric method. Rainfall use efficiency and Total water Use (CWU) was calculated according to Oweis *et al.,* 1998 by dividing mustard grain yield with the total precipitation received during the crop growing season.

$$\text{Rainfall water use efficiency (RWUE)} = \frac{\text{Mustard yield (q ha}^{-1})}{\text{Rainfall (mm)}}$$

Whereas, total water use (CWU) was worked out as per Allen *et al.*, 1998 using Pan evaporation data wherein relationship between ETo and Pan evaporation (PE) with Kc values based on percent growing season for determination of Etc

$$ETc = Kp \times Ep$$

Where

Ep = Pan evaporation (mm day[-1])

Kp = Pan coefficient

The oil content of the oven dried seeds was estimated by extracting oil using petroleum ether (60-80°C) as solvent and soxhlet apparatus (Sadasivam and Manickam, 1992). The oil yield q ha[-1] was calculated using following formula

Table 1: Effect of different moisture stress mitigation treatments on yield and yield attributes of Mustard

Treatments	No. of siliqua plant^{-1}		Seed Siliqua^{-1}		1000- seed weight (g)		Seed yield(q ha^{-1})	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
Control	349.33	211.33	8.07	8.33	3.08	2.61	8.57	9.77
Water spray at 50% flowering and 50% siliqua filling stage	392.67	224.33	9.00	10.07	3.41	3.00	10.00	10.17
1% urea spray at 50% flowering stage	400.00	230.00	9.60	10.67	3.50	3.11	10.97	10.47
1% urea spray at 50% siliqua filling stage	432.00	234.67	11.20	11.07	3.79	3.15	11.04	10.67
1% urea sprays at 50% flowering and 50% siliqua filling stage	440.00	242.33	11.87	11.27	3.82	3.21	11.60	11.00
0.05 % thio-urea spray at 50% flowering stage	464.67	231.67	12.67	11.47	3.85	3.16	11.84	10.55
0.05 % thio-urea spray at 50% siliqua filling stage	417.33	243.33	10.40	12.27	3.71	3.24	11.20	11.07
0.05 % thio-urea spray at 50% flowering and 50% siliqua filling stage	496.67	275.00	14.53	13.27	4.21	3.71	13.63	12.53
1% KNo_3 spray at 50% flowering stage	426.67	231.00	10.67	11.40	3.68	3.15	11.09	10.47
1% KNo_3 spray at 50% siliqua filling stage	407.33	241.00	10.40	12.13	3.56	3.22	11.06	10.93
1% KNo_3 sprays at 50% flowering and 50% siliqua filling stage	478.33	271.33	13.67	13.20	4.11	3.63	12.99	12.33
LSD ($p=0.05$)	45.42	24.85	1.61	1.74	0.29	0.33	1.42	1.24
SEm+	15.29	8.36	0.54	0.59	0.1	0.11	0.48	0.42

Oil yield (q ha^{-1}) = Seed oil content (%) × Seed yield (q ha^{-1}).

For economic evaluation the cost of cultivation, gross returns, net returns and B:C ratio were computed whereas the correlation of the grain yield, yield attributes and soil moisture parameters was calculated using SPSS 12.0 software

RESULTS AND DISCUSSION

Yield attributes and yield

The seed yield of Indian mustard increased significantly with application of agrochemicals viz. 1% urea, 0.05% 1% thiourea and potassium nitrate over control (water spray). Amongst the various agrochemicals, foliar application of two sprays of thio-urea @ 0.05% at 50% flowering followed by 50% siliqua filling stage not only increased the seed yield (12.53 q ha^{-1} to 1363.27 q ha^{-1}) and oil yield ha^{-1} (4.49 to 4.90 q ha^{-1}) of Indian mustard but also resulted in concomitant increase in the yield attributes namely number of siliqua plant^{-1} (275 to 496.67), no. of seed siliqua^{-1} (13.27 to 14.53), 1000-seed weight (3.71 to 4.21) besides the harvest index (25.81 to 32.41) than other treatments in comparison. However, it was found to be at par with twice application of potassium nitrate

Table 2: Effect of different moisture stress mitigation treatments on Harvest Index, Rainfal Water Use Efficiency, Cumulative water use and Economics of Mustard

Treatments	Harvest Index (%)		Oil yield (q ha^{-1})		Rainfall Water Use Efficiency (RWUE)		Cumulative Water Use (ETc)	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2012-13
Control	22.09	19.87	3.07	3.48	2.87	4.52	3.67	5.58
Water spray at 50% flowering and 50% siliqua filling stage	24.12	22.57	3.59	3.57	3.35	4.7	4.29	5.81
1% urea spray at 50% flowering stage	24.41	23	3.93.	369	3.68	4.84	4.7	5.98
1% urea spray at 50% siliqua filling stage	28	23.13	3.95	3.85	3.7	4.94	4.73	6.09
1% urea sprays at 50% flowering and 50% siliqua filling stage	28.34	23.67	4.17	3.94	3.89	5.09	4.97	6.28
0.05 % thio-urea spray at 50% flowering stage	29.9	24.11	4.25	3.75	3.97	4.88	5.08	6.02
0.05 % thio-urea spray at 50% siliqua filling stage	26.77	24.27	4.01	3.96	3.76	5.12	4.8	6.32
0.05 % thio-urea spray at 50% flowering and 50% siliqua filling stage	32.41	25.81	4.9	4.49	4.57	5.8	5.84	7.16
1% KNo_3 spray at 50% flowering stage	27.97	24	3.97	3.72	3.72	4.84	4.75	5.98
1% KNo_3 spray at 50% siliqua filling stage	25.85	23.67	3.99	3.96	3.71	5.06	4.74	6.24
1% KNo_3 sprays at 50% flowering and 50% siliqua filling stage	31.25	25	4.67	4.42	4.35	5.71	5.57	7.04
LSD (*p=0.05*)	2.15	2.64	0.5	0.41	0.48	0.57	0.61	0.71
SEm±	0.73	0.89	0.17	0.14	0.16	0.19	0.21	0.24

Table 3: Effect of different agrochemicals on economics and moisture status (content) of soil at 50 % flowering stage in Indian mustard

Treatments	Gross returns (Rs/ha)		Net returns (Rs /ha)		B:C ratio		Moisture content (%) 0-25 cm soil depth		Moisture content (%) 25-50 cm soil depth	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
Control	21423	29300	7973	15850	0.59	1.18	12.47	13.44	10.41	0.11
Water spray at 50% flowering and 50% siliqua filling stage	25000	30500	11100	16600	0.8	1.19	12.84	13.64	10.51	10.42
1% urea spray at 50% flowering stage	27440	31400	13499	17459	0.97	1.25	14.44	14.67	11.25	11.25
1% urea spray at 50% siliqua filling stage	27610	32000	13669	18059	0.98	1.3	14.07	14.48	11.32	11.28
1% urea sprays at 50% flowering and 50% siliqua filling stage	29002	33000	14570	18568	1.01	1.29	14.22	14.14	12.31	12.13
0.05 % thio-urea spray at 50% flowering stage	29606	31640	15256	17290	1.06	1.2	12.11	13.04	11.28	11.24
0.05 % thio-urea spray at 50% siliqua filling stage	28013	33200	13663	18850	0.95	1.31	12.45	14.23	11.38	11.33
0.05 % thio-urea spray at 50% flowering and 50% siliqua filling stage	34082	37600	18832	22350	1.23	1.47	12.48	13.38	11.44	11.29
1% KNo_3 spray at 50% flowering stage	27715	31400	9765	13450	0.54	0.75	11.88	14.88	10.97	10.87
1% KNo_3 spray at 50% siliqua filling stage	27652	32800	9702	14850	0.54	0.83	12.44	11.63	10.88	10.84
1% KNo_3 sprays at 50% flowering and 50% siliqua filling stage	32468	37000	10018	14550	0.45	0.65	12.87	14.17	10.81	10.88

Table 4: Effect of different agrochemicals on moisture status (content) of soil at 50 % siliqua filling stage in mustard

Treatments	Moisture content (%) 0-25 cm soil depth		Moisture content (%) 25-50 cm soil depth	
	2012-13	2013-14	2012-13	2013-14
Control	12.47	13.22	9.82	9.28
Water spray at 50% flowering and 50% siliqua filling stage	12.84	13.42	10.11	9.88
1% urea spray at 50% flowering stage	14.44	14.14	10.41	10.21
1% urea spray at 50% siliqua filling stage	14.07	13.98	10.48	10.32
1% urea sprays at 50% flowering and 50% siliqua filling stage	14.22	13.68	11.11	10.47
0.05 % thio-urea spray at 50% flowering stage	12.11	13.12	10.22	11.24
0.05 % thio-urea spray at 50% siliqua filling stage	12.45	15.25	9.88	11.33
0.05 % thio-urea spray at 50% flowering and 50% siliqua filling stage	12.48	14.88	9.84	11.29
1% KNO_3 spray at 50% flowering stage	11.88	13.2	9.87	10.34
1% KNO_3 spray at 50% siliqua filling stage	12.44	12.28	9.88	10.22
1% KNO_3 sprays at 50% flowering and 50% siliqua filling stage	12.87	13.24	10.12	10.54
CD (p=0.05)	-	-	-	-
SEm±	-	-	-	-

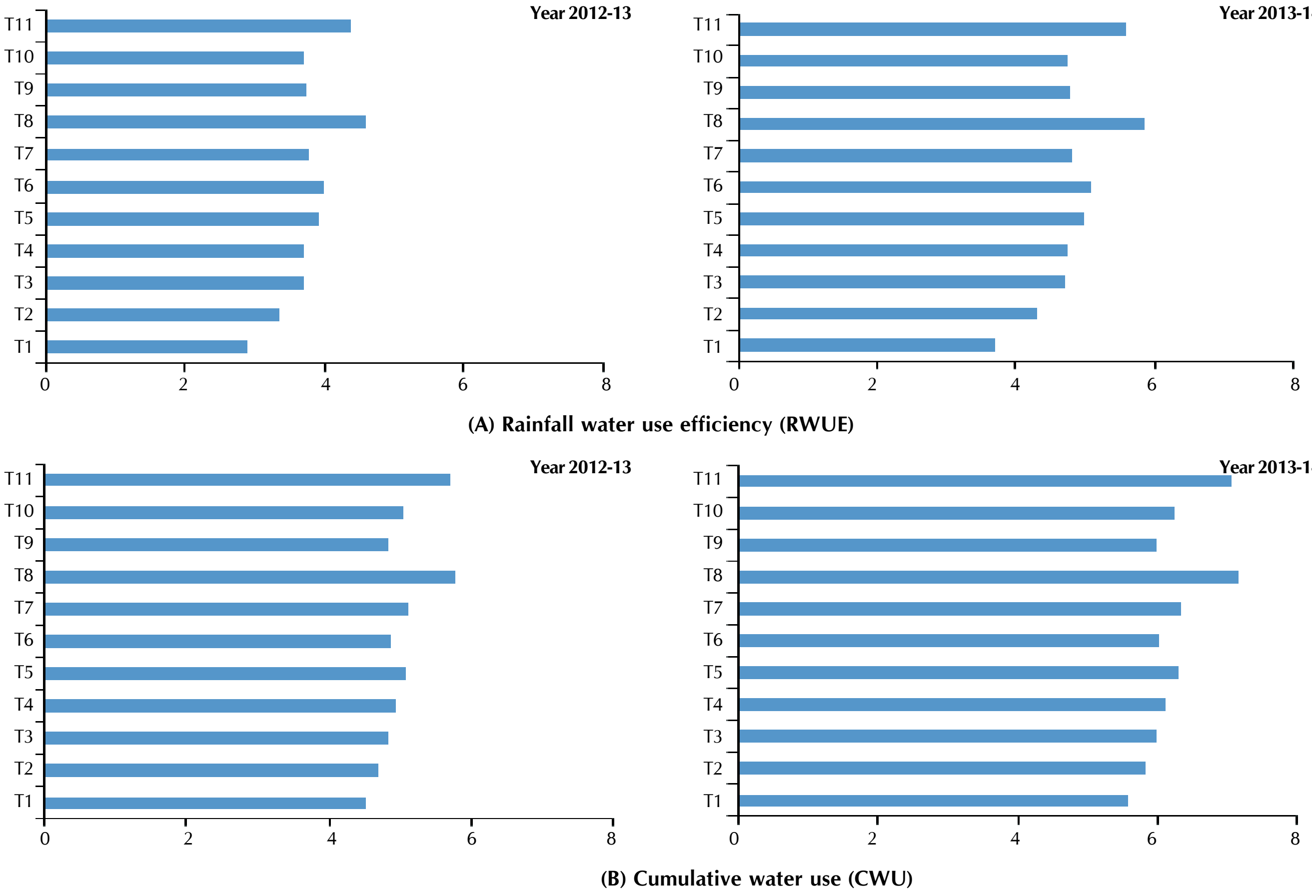

Figure 1: Effect of different agrochemicals on (A) Rainfall water use efficiency and (B) Cumulative water use during 2012-2014

@ 1% at both 50% flowering as well as 50% siliqua filling stage during both the years of experimentation (Table 1and 2). The significant increase in the yield as well as yield attributes may be due to increased moisture availability by enhancing the rainfall use efficiency and cumulative water use along with concomitant supply of critical nutrients viz. nitrogen and sulphur which influenced the metabolic reaction in the plant systems thereby resulting in delayed senescence of the crop which gave ample time to the crop to recover from the moisture stress and resulted in effective utilization of the available nitrogen as well as sulphur thereby increasing the chlorophyll content and photosynthesis which not only resulted in increased source strength but also helped in building up of more sink space i.e. structures for storage of more oil in the seeds of Indian mustard and structural development of the siliqua thereby resulting in more photosynthate transfer from source to the sink due to delayed senescence (Table 3 and 4). Similar beneficial results were also reported by Dadhich *et al*. 2014, Deshveer and Singh, 2003 and Premi *et al*., 2005.

Correlation studies

Highly significant and positive correlation was observed in seed yield with siliqua plant^{-1}, seeds siliqua^{-1}, 1000-grain weight, oil yield ha^{-1} and harvest index (Table 5). However, negative correlation was observed between seed yield of mustard and per cent moisture content at 0-25 cm soil depth at 50% flowering stage. The negative correlation observed between seed yield of mustard and per cent moisture content at 0-25 cm soil depth at 50% flowering stage clearly indicates that 50% flowering stage in Indian mustard is the most sensitive stage to moisture stress and foliar application of thiourea @ 0.05% resulted in significant increase in the seed yield due to increased rainfall use efficiency and cumulative water use (Fig. 1).

However, significantly positive correlation was observed between seed yield of Indian mustard and per cent moisture content at 25-50 cm soil depth at 50 % siliqua formation stage. However, higher moisture content at 25-50 cm soil depth was not found to affect the seed yield of Indian mustard significantly when they were subjected to foliar application of agrochemicals like urea, potassium nitrate and thiourea.

Economics

Twice application of thiourea @ 0.05% spray at 50% flowering followed by 50% siliqua filling stage resulted in higher net returns and B:C ratio than twice application of potassium nitrate @ 1% at both 50% flowering as well as 50% siliqua filling stage during both the years of experimentation (Table 2). Therefore, twice foliar application of thiourea @ 0.05% at 50% flowering stage and 50% siliqua filling stage can be recommended for moisture stress mitigation in Indian mustard under rainfed conditions of North India.

Table: 5 Correlation between seed yield, yield attributes, oil yield and moisture content at various crop growth stages and soil depth

	Grain yield	Siliqua plant^{-1}	Seed siliqua^{-1}	1000 seed weight	Harvest index	Oil yield	RWUE	WUE	Moisture (%) at 50% flowering stage (0-25cm)	Moisture (%) at 50% flowering stage (25-50 cm)	Moisture (%) at 50% siliqua filling stage (0-25cm)	Moisture (%) at 50% siliquafilling stage (25-50 cm)
Grain Yield	1											
Siliqua/Plant	.980**	1										
Seed/Siliqua	.977**	.988**	1									
1000 Seed weight	.990**	.987**	.980**	1								
Harvest Index	.944**	.982**	.981**	.964**	1							
Oil Yield	.999**	.978**	.980**	.989**	.942**	1						
RWUE	.998**	.969**	.967**	.981**	.928**	.997**	1					
WUE	.998**	.980**	.979**	.991**	.948**	.997**	.994**	1				
Moisture (%) at 50 % flowering stage (0-25cm)	-.037	-.046	-.123	-.011	-.070	-.054	-.034	-.076	1			
Moisture (%) at 50 % flowering stage (25-50 cm)	.483	.495	.508	.481	.518	.485	.479	.456	.423	1		
Moisture (%) at 50 % siliqua formation stage (0-25) cm	.185	.127	.071	.193	.061	.173	.191	.153	.785	.595	1	
Moisture (%) at 50 % siliqua formation stage (25-50 cm)	.649*	.691*	.699*	.663*	.721*	.644*	.623*	.638*	.226*	.906*	.461	1

Note:** Significant at the 0.01 level (2-tailed) *Significant at the 0.05 level (2-tailed); RWUE: Rainfall water use efficiency; WUE:; Water use efficiency

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