Environment and Ecology 41 (3D) :2062—2067, July—September 2023
Article DOI: https://doi.org/10.60151/envec/ZVFP3007
ISSN 0970-0420

Effect of Thiourea and Salicylic Acid on Growth and Productivity of Indian Mustard (*Brassica juncea* L.) under Moisture Stress Condition

Sampan Kamboj, Rajesh Kumar, Navjot Rana

Received 2 September 2022, Accepted 28 July 2023, Published on 20 September 2023

ABSTRACT

A field experiment was conducted at Experimental area, School of Agriculture, Lovely Professional University during the *rabi* season of 2021-22 to determine the effect of thiourea and salicylic acid on growth and yield of Indian mustard (*Brassica juncea* L.) under moisture stress condition. This experiment consists of 12 treatments were replicated thrice and was laid down Randomized Block Design. The application of thiourea and salicylic acid had significant effect on growth and yield of Indian mustard (*Brassica juncea* L.) under moisture stress condition. The maximum plant height (133.33 cm), number of branches (6.70), leaf area index (5.64), dry matter accumulation (17.32 g) at harvest, seed yield (2213.33 kg ha^{-1}), stover yield (5980.00 kg ha^{-1}) and harvest index (27.01%) were recorded under T_{12} treatment (thiourea spray @500 ppm at flowering + thiourea spray 500 ppm at siliqua initiation + 200 ppm salicylic acid at flowering) than rest of treatments. Application of thiourea spray @ 500 ppm at flowering + thiourea spray 500 ppm at siliqua initiation + 200 ppm salicylic acid at flowering indicated maximum plant height (cm), number of branches, leaf area index, dry matter accumulation (g) and productivity of Indian mustard with two irrigations. Thus, it can be potential alternative to increase Indian mustard production.

Keywords Thiourea, Salicylic acid, Indian mustard, Yield pray.

Sampan Kamboj[1] , Rajesh Kumar[2]*, Navjot Rana[3]

[2,,3]Assistant Professor
[1,2,3]Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara 144411, Punjab, India

Email : karnideshnoke@gmail.com
*Corresponding author

INTRODUCTION

India is one of the top nations in the world for the production of oilseeds. After grains, the oilseed crop is the second-largest agricultural product. The second-most significant edible oilseed crop in India is mustard (*Brassica juncea* (L.) Czern & Coss.), which provides around 50% of the population in all the northern states with the fat they need (Shivran *et al.* 2019). The mustard oil cake is produced over an area of around 68.57 lakh hectares and has a protein content of 40%. It also includes 5.1% nitrogen, 1.8% phosphorus, and 1.2% potassium (DES 2018). Due to the lack of winter rainfall, mustard responds to irrigation better. This crop's output was negatively impacted by its increased sensitivity to water fluctuations and its relative presence at key growth phases (Meena *et al.* 2013). The Indian mustard's production was improved by irrigation at crucial phases, possibly as a result of the plant's increased nutritional availability and more effective metabolic processes (Rai *et al.* 2017). Furthermore, it is generally agreed that timing irrigation during crucial crop growth phases would maximise the use of limited irrigation water (Saud *et al.* 2016).

Water used for irrigation often has an impact on rapeseed and mustard. The crop that requires the least amount of water is rapeseed-mustard (Meena *et al.* 2017, Sharma *et al.* 2018). Bioregulators may be utilized to alter the various metabolic and physiological processes of the plant to increase the yield of the mustard crop and lessen the negative effects of drought stress (Tiwari and Gangawar 2022). Thiourea is a sulfhydryl chemical and contains one SH group. The SH group has been connected to the translocation of photosynthetic cells in plants. It just concerns the activation of photosynthetic enzymes by light (Pandey *et al.* 2013). Salicylic acid (SA) applied exogenously has been shown to minimize the detrimental effects of water stress (Khan *et al.* 2015, Meena *et al.* 2018) and SA spray has also been shown to increase plant development (Nazar *et al.* 2015). The significant ammonium molecule glycinebetaine is regarded as one of the most prevalent and efficient osmoprotectants. The drought tolerance of plants was increased by the exogenous administration of glycinebetaine (Ahmed *et al.* 2021). In order to determine how bioregulators affect the buildup of dry matter in Indian mustard at various irrigation levels.

Thiourea, a sulphahydral chemical, is widely recognized for increasing the yield of oilseeds and for alleviating drought in subtropical areas (Sahu, 2023). It contributes significantly to the formation of certain metabolites, including essential oils and chlorophyll. Its use in rapeseed-mustard impacts the amount of protein, glucosinolate, and oil (Singh *et al.* 2017). Sulfur is consequently actively engaged in seed production and oil synthesis in rapeseeds, as has been demonstrated by several studies. In light of these facts, the current study assessed how Indian mustard (*Brassica juncea* L.) responded to thiourea and salicylic acid under moisture stress conditions in terms of growth and yield.

MATERIALS AND METHODS

An experiment was conducted during the *rabi* season of 2021-22 at the Experimental area, School of Agriculture, Lovely Professional University, Punjab. The experimental field has Sandy loam soil. The experimental site located at 31^0 15' N latitude and 750 41' E longitudinally at an elevation of 245m above mean sea level. The climate of an area is characterized as hot and dry summer and wet and humid monsoons. The test crop was Indian mustard and variety PBR-357. The ploughing layer of soil has pH (7.63), EC (0.35 dS m^{-1}), organic carbon (0.58%), available nitrogen (164.50 kg ha^{-1}), available phosphorus (25.3 kg ha^{-1}) and available potassium (324.58 kg ha^{-1}). The experiment was consisted of 12 treatments viz., T_1 (water spray), T_2 (thiourea spray 500 ppm at flowering), T_3 (thiourea spray 500 ppm at flowering + thiourea spray 500 ppm at siliqua initiation), T_4 (salicylic acid spray 100 ppm at flowering), T_5 (salicylic acid spray 150 ppm at flowering, T_6 (salicylic acid spray 200 ppm at flowering), T_7 (thiourea spray @ 500 ppm at flowering + salicylic acid 100 ppm at flowering), T_8 (thiourea spray @ 500 ppm at flowering + 150 ppm salicylic acid at flowering), T_9 (thiourea spray @ 500 ppm at flowering + 200 ppm salicylic acid at flowering), T_{10} (thiourea spray @500 ppm at flowering + thiourea spray 500 ppm at siliqua initiation + salicylic acid 100 ppm at flowering), T_{11} (thiourea spray @500 ppm at flowering + thiourea spray 500 ppm at siliqua initiation + 150 ppm salicylic acid at flowering) and T_{12} (thiourea spray @500 ppm at flowering + thiourea spray 500 ppm at siliqua initiation + 200 ppm salicylic acid at flowering) were replicated thrice and was laid down in Randomized Block Design. Furrows were opened at a spacing of 30×10 cm for the sowing of Indian mustard variety 'PBR-357.' with seed rate of 5 kg ha^{-1}. NP and K were applied as 40, 12 and 6 kg ha^{-1} by basal application. Nitrogen and phosphorus were applied through diammonium phosphate and urea and potash through murate of potash, respectively. The data were analyzed as per the standard procedure for "Analysis of Variance" (ANOVA) (Gomez and Gomez 1976).

RESULTS AND DISCUSSION

Growth

The data presented in Table 1 revealed that, different treatments of thiourea and salicylic acid had signifi-

Table 1. Effect of thiourea and salicylic acid on plant height (cm) and number of branches Indian mustard under moisture stress condition.

Treatments	Plant height (cm)			No. of branches		
	45 DAS	90 DAS	At harvest	45 DAS	90 DAS	At harvest
T_1	15.97	75.00	83.33	2.70	2.97	3.43
T_2	15.98	76.00	88.00	3.37	3.53	3.80
T_3	16.07	86.67	113.33	4.05	4.17	4.20
T_4	15.90	100.33	128.00	4.01	4.83	5.13
T_5	16.12	97.67	119.33	4.27	4.92	5.22
T_6	16.00	99.33	119.67	3.97	4.60	4.60
T_7	15.83	91.67	122.00	4.50	4.63	4.90
T_8	15.93	102.00	127.00	3.80	4.20	4.70
T_9	15.93	101.67	124.85	4.03	4.73	4.97
T_{10}	15.96	103.33	105.00	4.53	5.00	5.13
T_{11}	15.93	96.00	116.00	4.74	5.17	5.27
T_{12}	15.95	119.00	133.33	5.50	6.67	6.70
SEm±	0.09	2.52	4.10	0.13	0.17	0.16
CD (p=0.05)	N/A	7.45	12.10	0.37	0.49	0.47

T_1 (water spray), T_2 (thiourea spray 500 ppm at flowering), T_3 (thiourea spray 500 ppm at flowering + thiourea spray 500 ppm at siliqua initiation), T_4 (salicylic acid spray 100 ppm at flowering), T_5 (salicylic acid spray 150 ppm at flowering, T_6 (salicylic acid spray 200 ppm at flowering), T_7 (thiourea spray @ 500 ppm at flowering + salicylic acid 100 ppm at flowering), T_8 (thiourea spray @ 500 ppm at flowering + 150 ppm salicylic acid at flowering), T_9 (thiourea spray @ 500 ppm at flowering + 200 ppm salicylic acid at flowering), T_{10} (thiourea spray @500 ppm at flowering + thiourea spray 500 ppm at siliqua initiation + salicylic acid 100 ppm at flowering), T_{11} (thiourea spray @500 ppm at flowering + thiourea spray 500 ppm at siliqua initiation + 150 ppm salicylic acid at flowering) and T_{12} (thiourea spray @500 ppm at flowering + thiourea spray 500 ppm at siliqua initiation + 200 ppm salicylic acid at flowering).

cant effect on plant height, number of branches, leaf area index and dry matter accumulation (g) of Indian mustard under moisture stress condition. The maximum plant height (133.33 cm) was recorded under T_{12} treatment (thiourea spray @500 ppm at flowering + thiourea spray 500 ppm at siliqua initiation + 200 ppm salicylic acid at flowering) at harvest and lowest under (water spray) control (83.33 cm) at harvest. The treatment T_{12} was remained at par with T_4 (128.00 cm), T_8 (127.00 cm), T_9 (124.85 cm) and T_7 (122.00 cm). The highest number of branches (6.70), leaf area index (5.64) and dry matter accumulation (17.32 g) were observed under T_{12} treatment (thiourea spray @500 ppm at flowering + thiourea spray 500 ppm at siliqua initiation + 200 ppm salicylic acid at flowering) at harvest. This might be due to the adequate soil moisture increase the availability of the nutrient in the soil for the plant to increase in growth parameters by cell elongation and cell division this ascribed due to higher activity of auxin in plant tissues and photosynthesis activity of plant so they produced more food (Backer *et al.* 2018). The similar result recognized by Saeed *et al.* (2021), Müller and Munne-Bosch (2021) and Meena *et al.* (2018a). The foliar application of thiourea motivating the photosynthetic carbon fixation mechanism that enhanced the canopy of the plant (Sing and Meena 2019, Meena *et al.* 2019). Thiourea exhibits cytokinin activity (Suryavanshi and Buttar 2018) delaying the leaf senescence of the plant (Hönig 2018). The similar result reported by Singh *et al.* (2017) and Meena (2020).

Yield

Given the interaction of several internal and external elements, yield is a complicated attribute. The generation and mobilization of carbohydrates, the absorption of water and nutrients from the soil, as well as a number of external elements that the plant is exposed to during the growth season, all play a significant role in it. A close perusal of the data on seed and stover yield presented in Table 2 indicated that the application of thiourea and salicylic acid had significant effect on seed yield (kg ha^{-1}), stover yield (kg ha^{-1}) and harvest index (%) of Indian mustard under moisture stress condition. The maximum seed yield (2213.33 kg ha^{-1}), stover yield (5980.00 kg ha^{-1}) and harvest index (27.01 %) of Indian mustard were observed under T_{12} treatment (thiourea spray @500 ppm at flowering + thiourea spray 500 pm at siliqua

Table 2. Effect of thiourea and salicylic acid on leaf area index and dry matter accumulation (g) of Indian mustard under moisture stress condition.

Treatment	Leaf area index		Dry matter accumulation (g)		
	45 DAS	90 DAS	45 DAS	90 DAS	At harvest
T_1	2.55	4.38	2.97	4.88	9.26
T_2	2.59	4.81	3.01	5.85	12.46
T_3	2.81	4.75	3.16	6.14	13.19
T_4	3.05	4.97	3.32	6.43	12.27
T_5	2.93	4.88	3.42	6.52	14.64
T_6	2.91	4.94	2.97	6.86	14.75
T_7	3.00	5.14	2.24	6.94	16.12
T_8	2.93	4.82	3.43	6.61	13.60
T_9	2.92	4.56	3.03	6.93	13.46
T_{10}	2.89	5.20	3.30	6.80	16.05
T_{11}	3.13	4.44	3.45	6.82	16.82
T_{12}	3.43	5.64	3.73	7.62	17.32
SEm±	0.09	0.12	0.16	0.23	0.44
CD (p=0.05)	0.26	0.36	0.47	0.69	1.29

T_1 (water spray), T_2 (thiourea spray 500 ppm at flowering), T_3 (thiourea spray 500 ppm at flowering + thiourea spray 500 ppm at siliqua initiation), T_4 (salicylic acid spray 100 ppm at flowering), T_5 (salicylic acid spray 150 ppm at flowering), T_6 (salicylic acid spray 200 ppm at flowering), T_7 (thiourea spray @ 500 ppm at flowering + salicylic acid 100 ppm at flowering), T_8 (thiourea spray @ 500 ppm at flowering + 150 ppm salicylic acid at flowering), T_9 (thiourea spray @ 500 ppm at flowering + 200 ppm salicylic acid at flowering), T_{10} (thiourea spray @500 ppm at flowering + thiourea spray 500 ppm at siliqua initiation + salicylic acid 100 ppm at flowering), T_{11} (thiourea spray @500 ppm at flowering + thiourea spray 500 ppm at siliqua initiation + 150 ppm salicylic acid at flowering) and T_{12} (thiourea spray @500 ppm at flowering + thiourea spray 500 ppm at siliqua initiation + 200 ppm salicylic acid at flowering).

Table 3. Effect of thiourea and salicylic acid on seed yield (kg ha^{-1}), stover yield (kg ha^{-1}) and harvest index (%) of Indian mustard under moisture stress condition.

Treatment	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)
T_1	1150.00	4200.00	21.52
T_2	1216.67	4450.00	21.49
T_3	1280.00	4446.67	22.38
T_4	1623.00	4900.00	24.89
T_5	1802.00	5241.67	25.62
T_6	1952.00	5823.33	25.10
T_7	1884.33	5746.67	24.69
T_8	1785.00	5010.00	26.27
T_9	1863.33	5718.33	24.59
T_{10}	1853.00	5499.33	25.22
T_{11}	1990.00	5955.00	25.05
T_{12}	2213.33	5980.00	27.01
SEm±	24.80	102.47	0.50
CD (p=0.05)	73.19	302.47	1.46

T_1 (water spray), T_2 (thiourea spray 500 ppm at flowering), T_3 (thiourea spray 500 ppm at flowering + thiourea spray 500 ppm at siliqua initiation), T_4 (salicylic acid spray 100 ppm at flowering), T_5 (salicylic acid spray 150 ppm at flowering), T_6 (salicylic acid spray 200 ppm at flowering), T_7 (thiourea spray @ 500 ppm at flowering + salicylic acid 100 ppm at flowering), T_8 (thiourea spray @ 500 ppm at flowering + 150 ppm salicylic acid at flowering), T_9 (thiourea spray @ 500 ppm at flowering + 200 ppm salicylic acid at flowering), T_{10} (thiourea spray @500 ppm at flowering + thiourea spray 500 ppm at siliqua initiation + salicylic acid 100 ppm at flowering), T_{11} (thiourea spray @500 ppm at flowering + thiourea spray 500 ppm at siliqua initiation + 150 ppm salicylic acid at flowering) and T_{12} (thiourea spray @500 ppm at flowering + thiourea spray 500 ppm at siliqua initiation + 200 ppm salicylic acid at flowering).

initiation + 200 ppm salicylic acid at flowering) than rest of treatments. A non-physiological thiol called thiourea has increased the stress tolerance and productivity of crops like maize and mustard (Amin *et al.* 2013, Yadav *et al*. 2020). Thiourea was applied topically to boost biological and economic yield, and it was also linked to a rise in the movement of sucrose metabolites from source to sink (Pandey *et al.* 2013). The primary location for photosynthesis in *Brassica juncea* is the leaf, which is often referred to as the "source" for the production of photoassimilatory products, namely sucrose (Table 3). The word "sink" refers to mature seeds since they are primarily responsible for sucrose transfer away from leaves. The rate-limiting process for controlling the amount of photoassimilated in the sink and ultimately the crop yield is thought to be the sucrose translocation from source to sink (Aranjuelo *et al.* 2013, Aluko *et al.* 2021). Any plant's source strength is mostly controlled by how quickly sucrose is biosynthesized in active photosynthesizing leaves. Although the precise mechanism was not investigated, it is possible that the avoidance of oxidative photoinhibition at PSII or an overall increase in protein production, which also requires a lower redox environment, is to blame (Gururani *et al.* 2015).

CONCLUSION

In conclusion, thiourea spray @500 ppm at flowering + thiourea spray 500 ppm at siliqua initiation + 200 ppm salicylic acid at flowering indicated maximum plant height (cm), number of branches, leaf area index, dry matter accumulation (g) and productivity of Indian mustard with two irrigations. Thus, it can be potential alternative to increase Indian mustard production.

REFERENCES

Ahmed N, Zhu M, Li Q, Wang X, Wan J, Zhang Y (2021) Glycine betaine-mediated root priming improves water stress tolerance in wheat (*Triticum aestivum* L.). *Agriculture* 11 : 1127.

Ainsworth EA, Bush DR (2011) Carbohydrate export from the leaf: A highly regulated process and target to enhance photosynthesis and productivity. *Plant Physiol* 155: 64-69.

Aluko OO, Li C, Wang Q, Liu H (2021) Sucrose utilization for improved crop yields: A review article. *Int J Molecular Sci* 22: 4704.

Amin AA, El-Kader AA, Shalaby MAF, Gharib FAE, Rashad ESM (2013) Physiological effects of salicylic acid and thiourea on growth and productivity of maize plants in sandy soil. *Commun Soil Sci Plant Anal* 44: 1141-1155.

Aranjuelo I, Sanz-Saez A, Jauregui I, Irigoyen JJ, Araus JJ (2013) Harvest index, a parameter conditioning responsiveness of wheat plants to elevated CO_2 *J Exp Bot* 64: 1879-1892.

Backer R, Rokem JS, Ilangumaran G, Lamont J, Praslickova D, Ricci E, Subramaniam S, Smith DL (2018) Plant growth-promoting rhizobacteria: Context, mechanisms of action, and roadmap to commercialization of biostimulants for sustainable agriculture. Frontiers in Plant Science 9: 1473.

DES (2018) Directorate of Economics and Statistics, Ministry of Agriculture, www.agri.com

Ghosh PK, Hati KM, Mandal KG, Misra AK, Chaudhary RS, Bandyopadhyay KK (2000) Sulfur nutrition in oilseeds and oilseed-based cropping systems. *Fert Newsl* 8: 51-52.

Gomez KA, Gomez AA (1976) Statistical Procedures for Agricultural Research, 2nd edn. John Willey and Sons Inc. New York, USA.

Gururani MA, Venkatesh J, Tran LSP (2015) Regulation of photosynthesis during abiotic stress-induced photoinhibition. *Molecular plant* 8: 1304-1320.

Hönig M, Plíhalová L, Husičková A, Nisler J, Doležal K (2018) Role of cytokinins in senescence, antioxidant defence and photosynthesis. *Int J Molecular Sci* 19: 4045.

Khan MI, Fatma M, Per TS, Anjum NA, Khan NA, (2015) Salicylic acid on photosynthetic pigments and antioxidative enzymes of soybean plant. *Front Pl Sci* 6: 1-17.

Meena RK, Sharma DD, Chouhan GS, Shukla KB, Sumeriya HK, Padiwal NK (2013) Growth and productivity of mustard (*B. juncea* (L.) Czern & Coss.) as influenced by irrigation levels and agrochemicals. *Ann Agri-Bio Res* 18: 312-317.

Meena RS, Mitran T, Kumar S, Yadav G, Bohra JS, Datta R (2018) Application of remote sensing for sustainable agriculture and forest management. *Informat Process Agric* 5: 295-297.

Meena RS, Kumar S, Bohra JS, Lal R, Singh GS, Pandey A (2019) Response of alley cropping grown sesame to lime and sulfur on yield and available nutrient status in an acidic soil of Eastern India. *Energy Ecol Env* 4: 65-74.

Meena RS, Kumar V, Yadav GS, Mitran T (2018) Response and interaction of *Bradyrhizobium japonicum* and *Arbuscular mycorrhizal* fungi in the soybean rhizosphere: A review. *Pl Growth Regulat* 84: 207-223.

Meena RS, Meena PD, Yadav GS, Yadav SS (2017) Phosphate solubilizing microorganisms, principles and application of microphos technology. *J Cleaner Product* 145: 157-158.

Meena RS (2020) Nutrient Dynamics for Sustainable Crop Production. Springer, Singapore. ISBN: 978-981-13- 8659-6 DOI: https://doi.org/10.1007/978-981-13-8660-2.

Müller M, Munné-Bosch S (2021) Hormonal impact on photosynthesis and photoprotection in plants. *Plant Physiology* 185: 1500-1522.

Nazar R, Umar S, Khan NA, Sareer O (2015) Salicylic acid supplementation improves photosynthesis and growth in mustard through changes in proline accumulation and ethylene formation under drought stress. *South African Journal of Botany* 98 : 84-94.

Pandey M, Srivastava AK, D'Souza SF, Suprasanna P (2013) Thiourea, a ROS scavenger, regulates source-to-sink relation ship for enhanced crop yield and oil content in *Brassica juncea* (L.). *PloS One* 8: e73921

Rai RK, Singh VP, Upadhyay A (2017) Irrigation Scheduling. Planning and Evaluation of Irrigation Projects Methods and Implementation (Book) pp 385-412.

Saeed Q, Xiukang W, Haider FU, Kučerik J, Mumtaz MZ, Holatko J, Naseem M, Kintl A, Ejaz M, Naveed M, Brtnicky M, Mustafa A (2021) Rhizosphere bacteria in plant growth promotion, biocontrol, and bioremediation of contaminated sites: A comprehensive review of effects and mechanisms. *Int J Molecular Sci* 22: 10529.

Sahu MP. (2023). Role of sulfhydryl bioregulator thiourea in mitigating drought stress in crops. In Plant Stress Mitigators Academic Press, pp 293-304.

Saud RK, Singh BP, Pannu RK (2016) Studied on consumptive use, water use efficiency and moisture extraction pattern by Indian mustard as influenced by limited irrigation and nitrogen levels. *Intl J For Crop Improv* 7: 137-140.

Sharma P, Sharma HO, Rai PK (2018) Strategies and technologies for enhancing rapeseed-mustard production and farmer income. *Indian Farming* 68: 44-48.

Shivran A, Patel BJ, Gora M (2019) Effect of irrigation schedule and bio-regulators on yield attributes and yield of mustard (*B. juncea* (L.) Czern & Coss) crop. *Int J Chem Studies* 7: 1874-1877.

Sing A, Meena RS (2019) Effect of foliar spray of bioregulators and irrigation on dry matter accumulation of mustard (*Brassica juncea* L.). *Bangladesh Journal of Agricultural Research* 44: 689-693.

Singh A, Singh AK, Ashwin C (2017) Effect of hydrogel and thiourea on yield, quality and nutrient uptake of Indian mustard under moisture stress condition. *Res on Crops* 18: 42-48.

Srivastava AK, Nathawat NS, Ramaswamy NK, Sahu MP, Singh G (2008) Evidence for thiol-induced enhanced *in situ* translocation of 14 C-sucrose from source to sink in *Brassica juncea*. *Environ Exp Bot* 64: 250-255.

Suryavanshi P, Buttar GS (2018) Effects of exogenous osmoprotectants on physiological characteristics of wheat. *International Journal of Current Microbiology and Applied Sciences*

7: 1077-1089.

Tiwari A. Gangawar CB (2022) Impact of Foliar Spray of Bioregulators in Terminal Heat Stress Condition on Test Weight, Oil Content and Seed Viability of Mustard (*Brassica juncea* L.). *Asian Journal of Microbiology, Biotechnology & Environmental Sciences* 24 : 677-680.

Yadav T, Kumar A, Yadav RK, Yadav G, Kumar R, Kushwaha M (2020) Salicylic acid and thiourea mitigate the salinity and drought stress on physiological traits governing yield in pearl millet-wheat. *Saudi J Biological Sci* 27: 2010-2017.