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GROWTH, YIELD AND YIELD ATTRIBUTES OF MUSTARD VARIETIES AS INFLUENCED BY DIFFERENT GROWING CONDITIONS

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Abstract

As a step towards the profitable employment of nanoparticles in agriculture, effects of chitosan on mustard under water deficit stress (WDS) condition was investigated. Three growing conditions *viz.,* well water (WW), water deficit stress and foliar application of chitosan under WDS and three mustard varieties were considered in the experiment. Water deficit stress had negative effect on morpho-physiology and yield traits of mustard. However, the ameliorative effects of chitosan application were revealed by significant improvement in those traits. BARI Sharisha-15 produced the highest seed yield ha^{-1} (1.59, 1.39 and 1.55 ton, respectively) under WW, WDS and chitosan treated conditions. Based on overall responses, BARI Sharisha-14 may be considered as drought tolerant and Tori-7 as drought susceptible. Foliar application of chitosan can mitigate the harmful effects of WDS on morpho-physiology and yield of mustard.

Introduction

Mustard is a remarkable source of several macro and micronutrients (Majdoub *et al.* 2020) and contains less than 2-3% of erucic acid and 30 micromoles of glucosinolates (McVetty and Duncan 2015). Yield of mustard is very low in Bangladesh compared to other mustard growing countries of the world which is mainly due to non-availability of seeds of high yielding varieties, cultivation of traditional varieties and abiotic stresses like drought and high temperature stress (Alam *et al.* 2014). Low water availability during vital stages of its seed germination, growth, flowering, and pod filling severely caused impact on crop yield (Bandeppa *et al.* 2019).

Drought stress is regarded as one of the most major abiotic stresses, triggering an impediment in several crops' growth and production worldwide (Bandeppa *et al.* 2019) and its intensity is predicted to increase in the future under the changing climatic conditions (Tadayyon *et al.* 2018). Crop productivity is decreasing due to the effects of drought stress and minimizing these loses is a major area of concern for all nations to cope with the increasing food requirements. In Bangladesh, mustard being mainly grown in rain-fed condition which faces drought at different developmental stages. Different techniques like to screen drought tolerant variety or application of some bio-stimulators can decrease the adverse effects of drought. However, from a plants-soil perspective, the impacts of drought on soil moisture and plant productivity can be mitigated by application of organic amendment (Bindraban *et al.* 2020). There is an opportunity to combat water scarcity with the help of anti-transpirant by increasing water holding capacity of leaf and increasing leaf resistance to the diffusion of water vapour. Recently, chitosan has become one of the most preferred biopolymers due to its biocompatibility, antioxidant, biodegradability and non-toxic properties as well as compatible with various stresses such as drought (Dzung *et al.* 2011). Foliar spray of chitosan markedly stimulates plant growth, improves relative water content and uptake of essential nutrients and may reduce transpiration (Ahmed 2014) which improves plant tolerance to environmental stresses (Akbari *et al.* 2018, Sofy *et al.* 2020). So, foliar application of chitosan could be one of the approaches to combat water scarcity and to improve the mustard

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productivity under changing climatic condition of Bangladesh. Therefore, the study was conducted to unravel the interactive effect of WDS and chitosan on morpho-physiological and yield attributes of mustard to examine the protective effect of chitosan on productivity of mustard in relation to WDS.

Materials and Methods

The experiment was conducted at the research field and laboratory of the Department of Crop Physiology and Ecology, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh during November, 2020 to April, 2021. The experiment was laid out in a split plot design with three replications. Three growing conditions (well water, water deficit stress and foliar application of chitosan @ 50 ppm under water deficit stress) were placed as main plot treatment and three mustard varieties (BARI Sharisha-14, BARI Sharisha-15 and Tori-7) were randomly cultivated in sub plot. Well water plots were irrigated before flowering and at siliqua formation. No irrigation was given in water stressed plots after seedling emergence and no precipitation was allowed during experimental period by taking plastic covering over the water stressed plots. The chitosan solution of 50 ppm concentration was prepared by dissolving 50 mg of chitosan powder in 10 ml ethanol prior to dilution with distilled water. In order to improve the spray retention, 1% Tween 20 was mixed into the solution. Then distilled water was added to make the volume 1 litre to get 50 ppm chitosan solution. The chitosan solution was sprayed at 28 and 35 days after sowing (DAS) by a hand sprayer. Soil moisture content was calculated as dry weight basis from 15 cm depth of soil.

Relative leaf water content (RLWC) was calculated at flowering stage according to Kocheva *et al.* (2014). SPAD value of the fully expanded youngest leaf of the selected plants was estimated with the help of a SPAD meter (Model: SPAD-502, Minolta Co. Ltd, Japan) at flowering stage. Chlorophyll content of leaf was determined at 35 days after emergence according to Witham *et al.* (1986). Number of siliquae plant^{-1}, length of siliqua, number of seeds siliqua^{-1} of five selected plants were calculated and means were recorded. 1000-seed weight, seed yield plant^{-1} and seed yield m^{-2} were weighed using electric balance and converted to seed yield (t/ha). All the collected data were statistically analysed to find out the level of significance using Statistix 10 program and the means were compared by Tukey's test at $P \leq 5\%$ level.

Results and Discussion

Fig. 1 depicts that well water (WW) plots maintained higher soil moisture (27.46, 26.59 and 16.33%) compared to water deficit stressed (WDS) plots (18.21, 10.56 and 4.53%) as well as chitosan treated water deficit stressed plots (17.84, 11.83 and 4.79%) at 30, 60 and 80 DAS, respectively. The variation was due to unequal irrigation supply in well water and stressed plots. The variation was also might be due to variation in rate of evapotranspiration and consumption of water by plants from soil at early and later crop growth stages (Ali *et al.* 2018, Ray *et al.* 2020). The results indicated that the crop grown in non-irrigated plots suffered from water deficit stress. The finding corroborates with the reports of Haque *et al.* (2022) on wheat field, Haque *et al.* (2021) on maize field and Ahmed *et al.* (2021) on mung bean field.

The interaction effect of mustard varieties and growing conditions was significant on RLWC, SPAD value and chlorophyll content of leaf, siliquae plant^{-1}, siliqua length, seeds siliqua^{-1}, seeds plant^{-1}, 1000-seed weight, seed yield plant^{-1}, seed yield m^{-2} and seed yield ha^{-1} of mustard (Tables 1 and 2). Relative leaf water content of mustard was significantly decreased under WDS as compared with unstressed plants. Water deficit stress reduced the water content of mustard leaf by 19.22, 20.87 and 16.95% in BARI Sharisha-14, BARI Sharisha-15 and Tori-7, respectively as compared with well water. Foliar application of chitosan caused improvement in RLWC by 10.51, 17.35 and 5.62% in BARI Sharisha-14, BARI Sharisha-15 and Tori-7, respectively as compared with stressed plants. In this experiment, water deficit stress decreased RLWC which may occur due to the primary effects of drought involve reduction in water content at the cell, tissue, and organ levels (Farooq *et al.* 2009). Lowering in leaf water content due to drought was observed in rapeseed (Zhu *et al.* 2021) and in mustard (Mostafaei *et al.* 2018) that are very consistent to the present findings. The SPAD value of mustard leaf was decreased considerably due to adverse effect of water deficit stress but this could be increased substantially by foliar application of chitosan under WDS. The reduction due to WDS was more in Tori-7 (11.98%) than that of BARI Sharisha-14 (4.55%) and BARI Sharisha-15 (5.67%) as compared to well water, whereas the degree of increase due to chitosan application was 5.00, 4.79 and 5.73% in BARI Sharisha-14, BARI Sharisha-15 and Tori-7, respectively as compared to WDS. Significant reduction in SPAD value due to drought was observed in camelina and canola (Ahmad *et al.* 2021) that are parallel to these findings. Water deficit stress significantly reduced the chlorophyll content of mustard leaf by 12.80% in BARI Sharisha-14, 13.66% in BARI Sharisha-15 and 14.86% in Tori-7. Moreover, foliar application of chitosan under WDS showed significant increment in chlorophyll content of mustard leaf (9.79% in BARI Sharisha-14, 9.49% in BARI Sharisha-15 and 13.42% in Tori-7) as compared to stressed plants. The reduction in chlorophyll content of plant due to drought stress is a commonly observed phenomenon (Kumar *et al.* 2011) which might be due to reduced synthesis of the main chlorophyll pigment complexes encoded by the cab gene family (Allakhverdiev *et al.* 2003) and oxidative damage of chloroplast lipids and proteins (Lai *et al.* 2007).

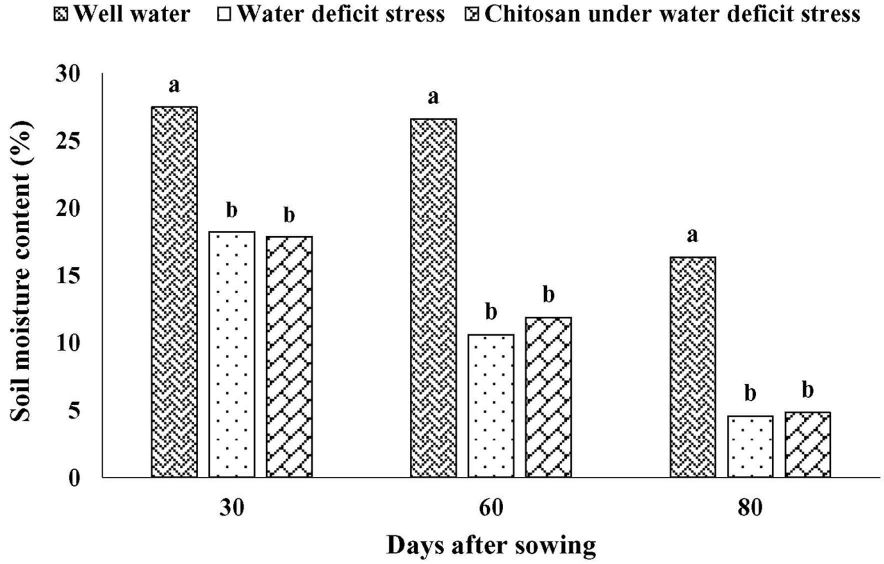

Fig. 1. Soil moisture content at different days after sowing of mustard.

Water deficit stress significantly reduced the siliquae number in mustard plant where chitosan caused significant increase in number of silique plant^{-1} as compared to water stressed plants. The degree of reduction due to WDS as compared to well water was 18.58% in BARI Sharisha-14, 17.52% in BARI Sharisha-15 and 20.93% in Tori-7. The degree of increase due to chitosan application as compared to WDS was 17.12, 11.59 and 15.02% in BARI Sharisha-14, BARI Sharisha-15 and Tori-7, respectively. Length of siliqua of mustard was significantly decreased due to water stress as compared to unstressed condition. Water deficit produced 9.04, 9.94 and 10.85% shorter siliqua in BARI Sharisha-14, BARI Sharisha-15 and Tori-7, respectively than that of well water. Foliar application of chitosan under WDS can alleviate the adverse effect of WDS in respect of siliqua length in mustard. The significant increase in siliqua length (6.44%) due to chitosan application was recorded in Tori-7. Other two varieties showed more or less similar increment in their siliqua length due to chitosan treatment as compared to untreated stressed condition. Reduced number of siliquae plant^{-1} and siliqua length under water deficit stress might be due to disturbance of the metabolic pathway of the plants and reduction of the availability of essential nutrients which are required for the growth and development of the plants. Singh *et al.* (2014) recorded shorter siliqua in mustard under limited irrigation compared to well irrigated plants that support the findings of this study. Water deficit significantly reduced the number of seeds siliqua^{-1} of mustard by 8.87, 12.79 and 12.45% in BARI Sharisha-14, BARI Sharisha-15 and Tori-7, respectively. On the other hand, foliar application of chitosan under WDS caused significant increment in the respective trait of mustard compared to stressed condition. Water deficit stress reduced the number of seeds plant^{-1} in all mustard varieties by different degree but the character was improved by different extends in different varieties due to exogenous application of chitosan as compared with WDS. The maximum decrease (30.78%) due to WDS and the minimum increase (21.30%) due to chitosan application were recorded in Tori-7 regarding the number of seeds plant^{-1} in mustard. The minimum decrease (25.79%) due to WDS and maximum increase (24.46%) due to chitosan application regarding number of seeds plant^{-1} were noted in BARI Sharisha-14. Water deficit significantly decreased 1000-seed weight of mustard by 14.44, 13.59 and 14.75% in BARI Sharisha-14, BARI Sharisha-15 and Tori-7, respectively compared to well water condition. Exogenous application of chitosan under WDS mitigated the adverse effect of WDS and significantly accelerated the 1000-seed weight of mustard as compared to WDS. Moreover, 13.69, 14.75 and 10.03% increase in 1000-seed weight was observed in BARI Sharisha-14, BARI Sharisha-15 and Tori-7, respectively due to foliar application of chitosan under WDS compared to untreated WDS condition. Water deficit significantly decreased the seed yield plant^{-1} where application of chitosan caused significant increase in that yield trait as compared to water stressed plants. The degree of decrease due to WDS as compared to well water was 36.53% in BARI Sharisha-14, 37.89% in BARI Sharisha-15 and 41.03% in Tori-7, while the degree of increase due to chitosan application as compared to WDS was 41.58, 38.46 and 33.73% in BARI Sharisha-14, BARI Sharisha-15 and Tori-7, respectively. Seed yield m^{-2} of mustard was significantly decreased due to water stress as compared to unstressed condition. Water deficit caused 13.38, 12.58 and 14.49% reduction in BARI Sharisha-14, BARI Sharisha-15 and Tori-7, respectively in respect to seed yield m^{-2} than that of well water. Foliar application of chitosan under WDS can ameliorate the adverse effect of water stress in respect to seed yield in mustard. The increase in seed yield m^{-2} due to chitosan application was 10.57% in BARI Sharisha-14, 11.51% in BARI Sharisha-15 and 10.17% in Tori-7. The results of the present study reveals that, BARI Sharisha-15 produced the highest seed yield ha^{-1} (1.59 ton) under well water condition which was statistically at par with seed yield of that variety (1.55 ton) under chitosan applied WDS condition. The seed yield ha^{-1} was substantially reduced in all mustard varieties under WDS condition compared to well water condition. The maximum reduction (14.49%) was recorded in Tori-7 which indicates more susceptibility of the variety to WDS regarding seed yield ha^{-1}. On the contrary, the minimum reduction (12.58%) due to WDS was noted in BARI Sharisha-15 which indicates more tolerance of the variety to WDS in relation to seed yield ha^{-1}. Foliar application of chitosan alleviated the adverse effect of WDS resulted in increase of seed yield ha^{-1} as compared to WDS. The maximum compensation (11.51%) in seed yield ha^{-1} due to chitosan application was observed in BARI Sharisha-15 which expresses more synergistic effect of chitosan on the variety under WDS regarding the trait. The lowest increment (10.17%) in seed yield ha^{-1} due to chitosan application was found in Tori-7 which indicates less stress mitigating effect of chitosan on the variety under WDS condition. Water deficit showed significant negative effect on number of siliquae plant^{-1}, siliqua length and number of seeds siliqua^{-1} which ultimately caused reduction in number of seeds plant^{-1} as the yield components are directly correlated with each other. Seed yield is the subsequent output of number of siliquae plant^{-1}, length of silique, number of seeds siliqua^{-1} and number of seeds plant^{-1} which were significantly decreased by the adverse effects of water deficit stress. Significant reduction in seed yield due to drought was reported earlier in mustard (Singh *et al.* 2018) and rapeseed (Shirani Rad *et al.* 2013) that are very consistent to present findings. The role of chitosan as an anti-transpirant in plants may be related to the fact that when deposited in the cell wall, promotes a decrease in stomatal conductance, increases the leave's resistance to water vapor loss through transpiration thus limiting the loss of water from leaf (Emam *et al.* 2014). In the present study, foliar application of chitosan significantly improved the physiological conditions and yield attributes of mustard than that of water deficit stress which might be due to improved physiological processes that eventually increase~~s~~ plant growth and development leading to increase in yield and yield contributing traits (Ibraheim and Mohsen 2015). Chitosan significantly increased the synthesis of chlorophyll and photosynthetic area of the plants as well as SPAD value of leaf under drought (Behboudi *et al.* 2018) which are in agreement to this study. Present findings are comparable with Mondal *et al.* (2013) who reported that chitosan application caused enhancement in mung bean yield. Muriefah (2013) also reported foliar applied chitosan increased yield in common bean under drought which corroborates with the present study.

Table 1. Physiological traits and yield components of mustard varieties under different growing conditions.

Mustard varieties	Growing conditions	Relative leaf water content (%)	SPAD value	Total chlorophyll content of leaf (mg g^{-1} FW)	Silique plant^{-1}	Length of siliqua (cm)	Seeds siliqua^{-1}
BARI Sharisha-14	G1	79.85ab	44.63bc	1.64ab	86.13a	5.20a	22.77a
	G2	64.50e (-19.22)	42.60cd (-4.55)	1.43c (-12.80)	70.13ab (-18.58)	4.73ab (-9.04)	20.75b (-8.87)
	G3	71.28d (+10.51)	44.73bc (+5.00)	1.57b (+9.79)	82.14a (+17.12)	4.88ab (+3.17)	22.05ab (+6.27)
BARI Sharisha-15	G1	81.56a	47.10a	1.83a	76.14ab	5.23a	23.37a
	G2	64.54e (-20.87)	44.43bc (-5.67)	1.58b (-13.66)	62.80b (-17.52)	4.71ab (-9.94)	20.38b (-12.79)
	G3	75.74c (+17.35)	46.56ab (+4.79)	1.73a (+9.49)	70.08ab (+11.59)	4.88ab (+3.61)	22.05ab (+8.19)
Tori-7	G1	78.66b	43.63bcd	1.75a	81.11a	4.70ab	20.48b
	G2	65.33e (-16.95)	38.40f (-11.98)	1.49c (-14.86)	64.13b (-20.93)	4.19c (-10.85)	17.93c (-12.45)
	G3	69.00d (+5.62)	40.60de (+5.73)	1.69ab (+13.42)	73.76ab (+15.02)	4.46bc (+6.44)	18.91bc (+5.47)
Level of significance		**	**	*	*	*	*
CV (%)		1.26	1.79	8.47	6.33	3.75	5.24

In a column, similar letter(s) did not differ significantly at 5% level, '*' and '**' indicate significance at 5 and 1% level, respectively. G1: Well water, G2: Water deficit stress and G3: Foliar application of chitosan under water deficit stress. Values in parenthesis with negative sign indicate the % reduction over well water and with positive sign indicate the % improvement over water deficit stress for respective variety.

Table 2. Yield components and yield of mustard varieties under different growing conditions.

Mustard varieties	Growing conditions	Seeds plant^{-1}	1000-seed weight (g)	Seed yield plant^{-1} (g)	Seed yield m^{-2} (g)	Seed yield (t ha^{-1})
BARI Sharisha-14	G1	1961.18a	3.67a	7.20a	142.00b	1.42b
	G2	1455.20cd (-25.79)	3.14d (-14.44)	4.57e (-36.53)	123.00de (-13.38)	1.23de (-13.38)
	G3	1811.20ab (+24.46)	3.57ab (+13.69)	6.47b (+41.58)	136.00bc (+10.57)	1.36bc (+10.57)
BARI Sharisha-15	G1	1779.39b	3.53ab	6.28c	159.00a	1.59a
	G2	1279.86ef (-28.07)	3.05de (-13.59)	3.90f (-37.89)	139.00b (-12.58)	1.39b (-12.58)
	G3	1545.26c (+20.73)	3.50ab (+14.75)	5.40d (+38.46)	155.00a (+11.51)	1.55a (+11.51)
Tori-7	G1	1661.13bc	3.39bc	5.63d	138.00b	1.38bc
	G2	1149.85f (-30.78)	2.89e (-14.75)	3.32g (-41.03)	118.00e (-14.49)	1.18e (-14.49)
	G3	1394.80d (+21.30)	3.18cd (+10.03)	4.44f (+33.73)	130.00cd (+10.17)	1.30cd (+10.17)
Level of significance		**	*	*	*	**
CV (%)		9.58	6.45	1.43	3.79	2.02

Abbreviations are similar as in Table 1.

From the overall results of the present investigation, it may be concluded that water deficit stress significantly influenced the morpho-physiological as well as yield traits and yield of mustard. Foliar application of chitosan under water deficit stress can mitigate the harmful effects of water deficit stress and significantly improve the morpho-physiological and yield traits of mustard compared to that of water deficit stress. Among the three mustard varieties, BARI Sharisha-14 could be selected as comparatively drought tolerant variety and Tori-7 as drought susceptible variety on the basis of morpho-physiological variation and yield performance under water deficit stress condition.

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