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Effect of drought stress on *Brassica* crops and its mitigation by inoculation of PGPR

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Abstract

Abiotic stress is one of major cause of reduction in growth and productivity of crops. Water deficient is drastic environmental stress that interacts with metabolic pathways and finally productivity of various plants. Members of family Brassicaceae (canola and mustard) are cultivated as oil yielding crops all over the world. Morphological and physiological parameters of plants are greatly affected by drought stress, which cause decline in productivity of crops. Water stress is responsible for significant reduction in the amount of linolenic acid and increases contents of glucosinolates in oil. Adaptation of different strategies for efficient use of soil moisture and reduction in drastic effect of drought has been a focal point for agriculture. In this aspect, one important strategy for enhancing the size of plant in water deficient condition is use of Plant Growth Promoting Rhizobacteria as inoculum. Plant Growth Promoting Rhizobacteria are naturally occurring in the rhizosphere which improve size of plants by various direct and indirect methods. PGPR also have potential to impart resistance in agricultural plants against unfavorable condition and can mitigate the deleterious effect of drought by processes known to as induce systemic tolerance (IST). Inoculation of plants with Plant Growth Promoting Rhizobacteria improves the metabolic processes of plant and consequently enhances the crop productivity. Owing to its importance, the present review describes the impact of water deficit condition on various morphological and yield parameters of *Brassica* crops as well as its mitigation by using inoculum of Plant Growth Promoting Rhizobacteria.

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Introduction

Water stress is a common problem, globally affecting the growth and yield of plants drasticaly and it become increase with alteration in present world climate change (Frommel *et al*., 1993). Across the globe, water deficit is one of basic constrains which reduces yield of cultivatable crops. The total land exposed to water scarcity become twice till 2000 all across the region. Agricultural crops are susceptible to water scarcity that decrease crop productivity worldwide (Dreesen *et al*., 2012; Rollins *et al*., 2013). Water deficient condition arise from both less rainfall and soil water during the growth of plants in agriculture which is required to maintain higher crop yield (Wahid *et al*., 2007; Sekhon *et al*., 2010; Vadez *et al*., 2011; 2012).

Being an important agricultural plant, *Brassica* species are mostly targeted by water deficient condition, because of the reason that they are mostly cultivated in arid and semiarid regions. Genus *Brassica* member of family Brassicaceae contains 100 species belongs to the family Brassicaceae, which comprises some 100 species, such as canola (*Brassica napus* L.), cabbage (*Brassica oleracea* L.), mustard (*Brassica juncea* L.), and turnip (*Brassica rapa* L.), which are basically cultivated for yielding oil, food or animal feed (Ashraf and McNeilly, 2004). European countries relays on canola for production of oil, while India and North Africa depend on mustard crop. Per annum yield of canola is greater than 60 million tons (www.faostat.fao.org, 2011). Among oil crops canola is third largest oil crop, cultivated in Northern Europe. Rapeseed is source of cooking oil and use for obtaining fuel and helpful in phytoremediation of heavy metals (Turan and Esringü, 2007). Rapeseed (*Brassica napus* L.) is one of significant agricultural crop contributed in world economy. Due to low amount of rain and unavailability of water for germination and growth remarkably reduce productivity. Growth parameters are greatly effected by water deficient conditions. Which leads a considerable reduction in seed and oil production. There is a need to find out strategies for efficient use of water for crop production. *Brassica* spp have the ability to stand with water deficient conditions that should be explored. One of important strategy for improving tolerance is association of plants with microbes.

Microbes can contribute to develop adaptation strategies and improving resistance to different stresses in crop plants. Plant-growth-promoting rhizobacteria (PGPR) are colonizing the roots of plant and efficiently cope up the effect of non living factors such as water deficient, salinity, heavy metals and cold on crops by the formation of biofilm and secretion of exopolysacchardies. Therefore, if stress is imposed on plants, microorganisms present in the rhizosphere affect plant cells by various ways such as production of compatible osmoprotectors. During the plant growth, microbes could play a role by (a) stimulation of metabolic processes in soil (population of microbes, working of enzymes and variety); (b) detector of soil health; (c) alleviation of deletrious effects of stresses; and (d) important rhizospheric microbes as inoculum's (Kastori *et al*., 2006; Milosevic *et al*., 2008; Grover *et al*., 2010). In order to cope up with stress different Plant Growth Promoting Rhizobacteria are effective inoculum in different crop plants. Present review summarizes the effect of deficiency of water on *Brassica* spp as well as its mitigation by using Plant Growth Promoting Rhizobacteria.

Effects of Drought Stress on Morphology of Plants

Drought is one of basic constrain which inhibits plant germination and growth. Division and increase in cell size both drastically effected by water limitation (Anjum *et al*., 2003a; Kusaka *et al*., 2005). Oil seed rape is normally regarded to be more susceptible to water deficit as compared to wheat. However, drought stress cause various deletrious effects according to the period of stress and phase of plant growth. Rahnema and bakhshande (2006) demo nstrated that the remarkable decrease in productivity was occurs due limitation of irrigation in spring. Impact of water deficient depends upon the stress duration, genotype, amount of stress and growth stage of *Brassica*.

Water stress cause reduction in plant height, size of leaves, number of tillers, amount of oil in seed, chlorophyll content and rate of photosynthesis of canola cultivar (Moaveni *et al*., 2010). Drought stress effects various growth phases of plants (Dicken and Wright, 2008).

Reduction in availability of water results decrease in growth of leaves and disturb stomatal opening and closing mechanism (Qaderi *et al*., 2006). Production of maximum leaf area is necessary for photosynthesis and finally for yield. Drought stress commonly decrease size of leaves in various plants of genus *Brassica* and *Glycine max* (Zhang *et al*., 2004; Farooq *et al*., 2009). Leaf development is more susceptible to drought in cereals as compared to oil crops (Manivannan *et al*., 2007b & 2008). Water deficit stress cause significant reduction in shoot length due to decrease in division and expansion of canola plant (Shafi *et al*., 2009; Ashraf *et al*., 2013). Growth of stem was reduce in water stress in soybean crop (Specht *et al*., 2001). One of common injurious impact of drought on agricultural plants is decrease in production of plant biomass (Farooq *et al*., 2009). The reason of decline in biomass production is reduction in activity of enzymes involve in metabolism during condition of stress (Hong and Ji-Yun, 2007; xu *et al*., 2008), Production of plant biomass biomass was associated with water content and plant dependence on water. *B. carinata* indicates less relative water content and produce considerably low biomass. But, it has a potential to increase water potential of leaf at drooping stage as compared to other species of *Brassica*. On the contrary, Canola has high relative water content and produce more biomass. But, water and osmotic potential is relatively less. It is confirmed by pervious studies that rapeseed is more tolerant to water deficient, followed with *B. juncea* and *B. rapa*. While among susceptible crops *B. carinata* is the most common (Zhu *et al*., 2011).

Reduction in yield under drought was recorded many cultivars of sunflower (Tahir & Mehid, 2001). Under water limited condition, absorbance of water take place by well-developed root system (Toorchi *et al*., 2002). Drought stress remarkably enhances length of root, fresh and dry biomass of canola. Active intake of water and essential solutes by plant depends on efficient root system (Li *et al*., 2006).). In sunflower, efficient root system was recorded in water deficit condition. Improvement in shoot and root biomass in water deficit is associated to concentration of ABA in shoot and root (Sharp & LeNoble, 2002; Manivannan *et al*., 2007b). Moreover, not only growth factor are effected by drought but also other metabolic processes such as cell turgidity, photosynthesis are inhibited (Tahir *et al*., 2007). Reduction in photosynthesis results due to drought (Huax *et al*., 1997). Limited water availability enhance production of mobile electrons which results in oxidative stress. Oxidative stress enhance number of reactive oxygen species (ROS) (Tohidi *et al*., 2009). Water deficit cause significant reduction in biomass, chlorophyll content and impose oxidative stress in *Brassica juncea*, *Brassica napus*, *Brassica compestris*. However *Brassica juncea* had shown less damage due to drought as it is more tolerant to drought compared to other species of *Brassica*.

Effect of Drought on Yield and Related Traits

Brassica spp is an important agricultural crops in various arid and semiarid regions for production of oil. Where its productivity is mostly limited due to drought stress and high temperatures during the reproductive stage. *Brassica napus* ranks third highly cultivable crop for oil production. Canola is an important source of cooking oil and use as biofuel as well as phytoremediation of organic pollutants (Turan and Esringü, 2007). Both vegetative and reproductive growth of rapeseed is affected by drought. Flowering stage of canola is more sensitive to water deficit condition (Ghobadi *et al*., 2006). Past research proved that water deficit condition considerably reduce the amount of oil in seeds of canola (Sinaki *et al*., 2007). Nasri *et al*. (2008) describe that imposing drought condition leads a considerable decrease in siliquae number per plant, seeds number per siliquae, weight of 1000 seeds and amount of oil in five canola varieties. Decrease in photosynthetic reaction leads to pod termination, subsequently reduction in pods number (Dicpenbrock, 2002).

Transport of water within the plant is conducted by difference in water potential between leaf and xylem. Water stress cause reduction in water potential which unbalance the potential difference between leaf and xylem. This results reduction in seeds number per pod in drought (Sieling *et al.*, 1997). Reduction in weight of seed is related to decline in number of seed in pod as well as in plant. Drought stress has great influence on source and sinks storage potential and considerably leads to decline in weight of seed. Sinaki *et al.* (2007) also observed that drought stress at flowering stage to the harvesting of 29 canola varieties cause decline in yield of seed, the productivity, and the pods number; moreover, seeds number per pod was not much affected. Lipids content, amount of protein and oil of canola are also influenced due to water deficit condition, as recorded by Aslam *et al.* (2009). When water deficit stress increase from medium conditions to high conditions in growing stage, cause reduction in saturated fatty acid and oleic acid, however increase take place in linolenic and linoleic acid . More ever, 3.2% of oil content of seed reduce and 3.9% protein in meal improved in water deficit condition. Water stress cause sharp decline in branches of plant, pods number and the amount of seeds per pod of water deficit susceptible varieties lines, while in drought-tolerant cultivars this decline was not considerable. The decline in amount of oil in seeds of oil crop during water deficit is a general response (Ali *et al.*, 2009). Drought stress effect the quality of canola oil by reducing the linolenic acid and increasing the glucosinolates. Oil concentration of nuts was reported to reduce during water deficit condition (Dwivedi *et al.*, 1996). A reduction in productivity, oil content and all growth parameters were reported in *Brassica napus, Brassica juncea, Brassica rapa* (Pooya *et al.*, 2012).

Impact of water limitation on sunflower productivity is complicated because of relation among the duration and amount of stress associated with growth stages that establish the yield components. Imposing drought on bud initiation phase of sunflower was most pronounced to seed productivity as compared to filling stage of seeds (Prabhudeva *et al.*, 1998). Wheat productivity parameters such as seed number and size were reduce under pre-anthesis water limitation (Edward and Wright, 2008).

Various studies on corn, water deficit significantly decrease the seed production that is due to defoliation at initial flowering stage (Kamara *et al.*, 2003; Monneveux *et al.*, 2006). Drought condition decrease productivity of seed in *Glycine max*. Seed production of drought-exposed soybean plants was less relative to normal watered plants (Specht *et al.*, 2001). Water deficit at flowering and seed filling phase of sunflower for 12 days cause drastic reduction in achene yield (Mozaffari *et al.*, 1996; Reddy *et al.*, 2004), productivity of seeds in bean and green gram (Webber *et al.*, 2006), corn (Monneveux *et al.*, 2006) and *Petroselinum crispum* (Petropoulos *et al.*, 2008).

Role of PGPR in Improving the Growth of Plants Under Stress Condition

Plant Growth Promoting Rhizobacteria are beneficial rhizospheric bacteria which can improve development processes in plants by various direct mechanisms like fixing nitrogen for plants, improving the absorbing capacity of nutrients for the plant, producing growth stimulating hormones and vitamins like auxin, Cytokinin and Gibberllin and indirect ways like production of antibiotics, discharging rhizosphere from iron, competing with microbial species, inducing systemic resistance in the plant, and improving the plant survival against stresses caused by environmental components (Glick *et al.*, 1999). Rhizospheric bacteria can be used for promoting growth of plants instead of chemical fertilizers due to their ability of improving growth of plants. Both fungi and bacteria can inhibit the pathogenic organisms and improving plant growth and this become useful tool in agricultural system (Yasri *et al.*, 2009). The improvement in growth of crops with PGPR reveals their ability as biofertilizers for agricultural field. Bertrand *et al.* (2001) isolated strains of genus *Varivorax*, *Agrobacterium*, *Phyllobacteriumas* and *Pseudomonas* very effective PGPR linked to *Brassica* crops.

Rhizobium spp. fix atmosphering nitrogen associated with roots of legume crops where they form nodules. It has been used as inoculants at commercial scale and label as biofertilizer first time (Kannaiyan, 2002).

Rhizospheric bacteria, which improve growth of various crops, like cereals, oil crops and legumes have been documented in various studies (Kloepper *et al.*, 1988; Chanway *et al.*, 1989). These bio-fertilizer are environmental friendly, stable soil structure and nutrient availability to increase size of plants. It has been revealed that positive effect of bio-fertilizer is not restricted to legumes only, but also beneficial to non-legumes. These microbes perform multiple functions in plant growth i.e. *Azotobacter* and *Azospirillum* improve plant growth by fixing nitrogen and producing active substances which is helpful for growth of reproductive organs and enhance yield (Rodriguez *et al.*, 2004; Yasari *et al.*, 2009).

Plant Growth Promoting Rhizobacteria (PGPR) enhance growth of plants by various mechanisms like fixation of nitrogen, secretion of phytohormones such as auxin, cytokinins and gibberellins, iron sequestration by production of siderophores and excretion of ACC deaminase (Glick *et al.*, 1999). In addition to direct mechanism, some indirect mechanisms like production of antimicrobial substances, limited availability of iron for pathogens are also helpful in plant growth promotion (Bashan *et al.*, 2004). Perivous reports indicates that *Azospirillum lipoferum* was act as representative PGPR to establish beneficial correlation among PGPR and cereals. Genus *Azospirillum* produce different kind of growth promoting substances in close association of roots. However, its plant growth promoting potential is not for particular crop and it can promote growth in crops, which have no pervious history of *Azospirillum* strains (Shukla *et al.*, 2002). Various species of *Azospirillum* are customarily separated from agricultural crops, with conventional isolation from canola.

Bacterial inoculation had produced more significant results on development and growth of maize plants under different soil conditions. Size of plant, leaf size, grains number was significantly increased after inoculation with different bacterial strains. Nosheen *et al.*, (2011) reported that *Azospirillum* inoculation significantly increase leaf and seed protein content, leaf chlorophyll content. Inoculation has significant effect on yield parameters, improve oil content, seed size and 1000 seed weight. Arzanesh *et al.*, (2011) was conducted a research experiment by inoculating canola with *P. putida*. The results showed that inoculation had increased the shoot biomass as compared to un-inoculated plants. Inoculation of *Azospirillum* strain leads to increase root area and formation of lateral roots (Creus *et al.*, 2004). Amount of chlorophyll in inoculated plants was considerably high in comparison to untreated plants under water defcit condition. Significant increase in amount of proline was observed by inoculation in water stress (Casanova *et al.*, 2002). Inoculation also enhances sugar content of plant in water deficit condition. Same results of inoculation were documented in cereals by Bano *et al.*, (2013). Quantity of amino acid in corn crop has been increase with inoculation of PGPR by exposure of water stress (Bano *et al.*, 2013). Nosheen *et al.*, (2011) documented that *Azospirillum* significantly increase leaf and seed protein content, leaf chlorophyll content. Inoculation has significant effect on yield parameters, improve oil content, seed size and 1000 seed weight.

Conclusion

Drought stress affects morphology, physiology and yield of various plant species in field conditions. Water stress drastically effect the oil quality of *Brassica* spp like canola, mustard plant as it cause reduction in various parameters such pods number in plant, weight of seed, seeds number in one pod. Tolerance to water deficit is vary in different species of *Brassica*. On of effective strategy for increasing tolerance and survival of plants under drought stress is treatment of rhizospheric bacteria.

This review favour contribution of growth promoting bacteria as inoculant, as this Promoting Rhizobacteria have ability for improving growth of *Brassica* under drought condition. Plant Growth Promoting Rhizobacteria helps the plant to improve the tolerance for surviving in water deficit condition.

This potential of growth promoting bacteria for mitigating drought stress is open a new chapter for implementation of rhizospheric bacteria for agriculture. Isolation and inoculation of stress tolerant Plant Growth Promoting Rhizobacteria are focal point for agriculture in future.

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