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Effect of Mulches and Micronutrients on Water Use and Water Use Efficiency of Broccoli (*Brassica oleracea var. italica*)

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Abstract

Broccoli (*Brassica oleracea var. italica*) is an important cole crop valued for its high nutritional and medicinal properties. Efficient utilization of water is essential for sustainable broccoli production, particularly under rainfed and moisture stress conditions. A field experiment was conducted at the Horticultural Farm of Palli-Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan, West Bengal to study the effect of mulches and micronutrients on water use and water use efficiency of broccoli. The experiment revealed that mulching and micronutrient application significantly influenced water use and water use efficiency. Paddy straw mulch @ 7 t ha^{-1} remarkably reduced water use (201.46 mm) compared to no mulch treatment (276.80 mm), saving about 75.34 mm water. Among micronutrient treatments, Zn @ 1% + B @ 0.5% recorded the lowest water use (228.53 mm) and highest water use efficiency (71.54 kg ha^{-1} mm^{-1}). The interaction effect showed that paddy straw mulch combined with Zn @ 1% + B @ 0.5% recorded minimum water use (195.50 mm) and maximum water use efficiency (88.54 kg ha^{-1} mm^{-1}). The study concluded that application of paddy straw mulch along with zinc and boron foliar spray effectively conserved soil moisture and improved water use efficiency in broccoli.

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Keywords

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Introduction

Broccoli (*Brassica oleracea var. italica*) is one of the most important cole crops in the world belonging to the family Brassicaceae (Cruciferae). It contains a high amount of Vitamin-A (9000 IU/100 g) and protein (3.5%) (Friedman, 1996). Moreover, it is a rich source of antioxidants, phenolics, vitamins and bioactive compounds such as sulphoraphane, dietary fibre, minerals and folates. These compounds help prevent chronic diseases including cancer and cardiovascular disorders (Jeffery *et al.,* 2003). Broccoli has gained commercial importance in India and is increasingly cultivated in the red lateritic belt of West Bengal due to its high market demand (Nonnecke, 1989).

Water is a critical factor for crop growth and development. Proper water balance through irrigation improves cell turgidity, nutrient availability and translocation of photosynthates, thereby enhancing crop growth and yield (Ali and Kushwaha, 1987). However, efficient use of water is a major challenge in Indian agriculture, especially in rainfed regions where water scarcity and high evapotranspiration limit vegetable production during the rabi season.Among various water conservation practices, mulching has proved to be

simple, economical and effective. Mulches reduce evaporation losses, improve soil environment, conserve soil moisture and increase crop productivity (Reddy and Reddy, 2007; Bhatt and Khera, 2006; Ekinci and Dursun, 2009). Micronutrients like zinc and boron also play an important role in water relations, nutrient metabolism and crop productivity. Keeping these aspects in view, the present investigation was undertaken to study the effect of mulches and micronutrients on water use and water use efficiency of broccoli.

Materials and Methods

The field experiment was conducted at the Horticultural Farm, Institute of Agriculture, Visva-Bharati University, Sriniketan, West Bengal, India. The experimental site is situated in the semi-arid sub-humid region of West Bengal at 23°42′ N latitude and 87°40′30″ E longitude. The soil of the experimental field was sandy loam in texture with pH ranging from 5.8 to 6.1 and low organic matter content (0.63%).

The experiment was laid out in a split plot design with three mulch treatments in the main plots and nine micronutrient treatments in the sub-plots, resulting in twenty-seven treatment combinations. The field was prepared by ploughing followed by harrowing to obtain a fine tilth. Farm Yard Manure (FYM) @ 20 t ha^{-1} was incorporated during land preparation. The crop was fertilized with the recommended dose of N:P @ 100:80:100 kg ha^{-1} through urea, single super phosphate (SSP) and muriate of potash (MOP), respectively. Full doses of phosphorus and potassium along with half dose of nitrogen were applied as basal, while the remaining nitrogen was top dressed at 30 days after transplanting (DAT).

Healthy broccoli seedlings were transplanted at a spacing of 60 cm × 40 cm. Mulches were applied uniformly after proper establishment of seedlings. Life-saving irrigation was provided uniformly to all plots whenever necessary. Foliar application of micronutrients was carried out at 30 and 45 DAT. All other recommended package of practices were followed uniformly throughout the crop growth period.

Water use was estimated using the soil moisture depletion method based on soil moisture percentage and bulk density of soil. Water use efficiency was calculated by dividing head yield by consumptive use of water and expressed as kg ha^{-1} mm^{-1}.

Water use

Water use was determined from the moisture percentage data and bulk density (g/cc) of the soil respective depth using the water depletion method in each plots. Consumptive use of water by the crop was computed by the following equation.

$$U = \sum_{i=1}^{n} \left(\frac{M2 - M1}{100} \right) XBdixDi + ER$$

Where,

- U=water use (cm) during a given period
- Cu=Total seasonal water use (cm)
- M_1=Soil moisture percentage of initial soil sample or just after rainfall/irrigation
- M_2=Soil moisture percentage of next soil samples or at harvest
- Bdi=Bulk density of soil at i^{th} layer of soil (g/cc)
- n= Number of soil layers in the root zone (0-15 and 15-30cm)
- ER= Effective rain fall during crop growth period

Water use efficiency

Water use efficiency was calculated by using the following expression WUE=Y/wu, where Y is the head yield kg/ha and "CU'' is consumptive use of water (mm). Water use efficiency was expressed in kg/ha/mm

Results and Discussion

Water Use

Water use during the crop period was significantly influenced by mulches, micronutrients and their interactions.

Among the mulching treatments, paddy straw mulch @ 7 t ha^{-1} (M_1) significantly reduced water use to 201.46 mm compared to water hyacinth mulch and no mulch treatment.

The maximum water use (276.80 mm) was observed under no mulch condition (M_3) (Fig.1).

Application of paddy straw mulch saved about 75.34 mm water and reduced water requirement by 37.39% over no mulch treatment. Among micronutrient treatments, Zn @

1% + B @ 0.5% (mn_6) recorded the lowest water use (228.53 mm), followed by mn_8 (230.22 mm) and mn_9 (231.58 mm). The highest water use (238.01 mm) was recorded in plants without micronutrient application (mn_1). The interaction effect between mulches and micronutrients was significant (Fig.1).

The lowest water use (195.50 mm) was observed in plants grown under paddy straw mulch with Zn @ 1% + B @ 0.5% (M_1mn_6). This treatment was statistically at par with M_1mn_8 (197.42 mm), M_1mn_9 (199.46 mm) and M_1mn_5 (200.23 mm). The highest water use (281.97 mm) was recorded under no mulch and no micronutrient application (M_3mn_1).

Water Use Efficiency

Application of mulches and micronutrients significantly influenced water use efficiency in broccoli. Paddy straw mulch @ 7 t ha^{-1} recorded the highest water use efficiency (75.00 kg ha^{-1} mm^{-1}), which was significantly superior to water hyacinth mulch and no mulch treatments (Fig.1). The lowest water use efficiency (46.43 kg ha^{-1} mm^{-1}) was observed under no mulch condition.

Among micronutrient treatments, Zn @ 1% + B @ 0.5% (mn_6) recorded maximum water use efficiency (71.54 kg ha^{-1} mm^{-1}). Treatments mn_8 (68.25 kg ha^{-1} mm^{-1}) and mn_9 (65.75 kg ha^{-1} mm^{-1}) were statistically at par. The lowest water use efficiency (49.51 kg ha^{-1} mm^{-1}) was recorded in plants without micronutrient application.

Combined application of mulches and micronutrients further enhanced water use efficiency. The highest water use efficiency (88.54 kg ha^{-1} mm^{-1}) was observed under paddy straw mulch with Zn @ 1% + B @ 0.5% (M_1mn_6), followed by M_1mn_8 (85.15 kg ha^{-1} mm^{-1}). The lowest water use efficiency (38.12 kg ha^{-1} mm^{-1}) was recorded under no mulch and no micronutrient application (M_3mn_1) (Fig.1).

Water use and water use efficiency are closely related parameters determining crop productivity under limited water conditions. In the present study, paddy straw mulch significantly reduced water use and enhanced water use efficiency. The superior performance of paddy straw mulch may be attributed to its thick protective cover over the soil surface, which reduced evaporation losses and conserved soil moisture.

Previous studies reported that straw mulching improves soil moisture retention, infiltration and crop productivity under arid and semi-arid conditions (Chen *et al.,* 2007; Adekalu *et al.,* 2007; Balwinder *et al.,* 2011; Olasantan, 1999). Better soil moisture conservation under mulch might have enhanced nutrient availability and improved crop growth.

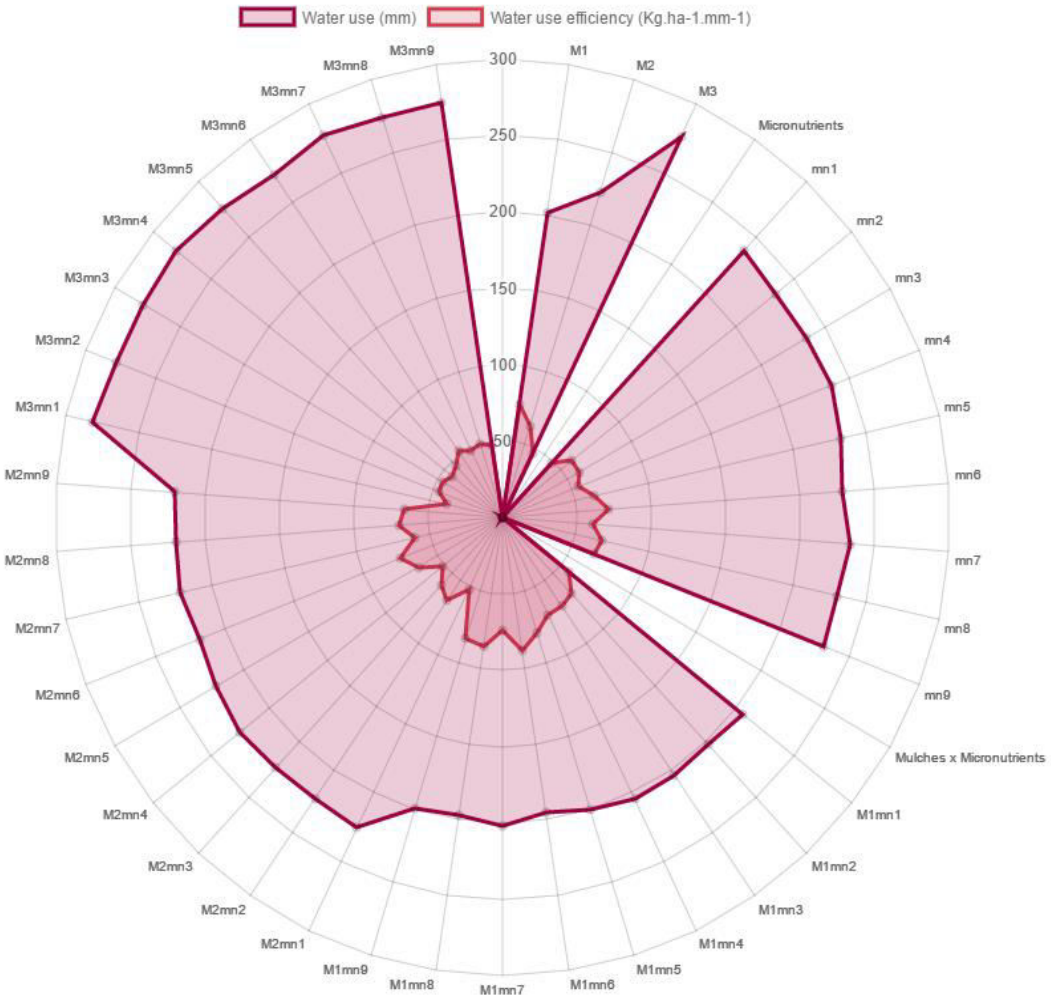
In contrast, unmulched plots exhibited greater evaporation due to direct exposure of soil to sunlight, resulting in higher water use and lower water use efficiency. Zinc plays an important role in osmotic adjustment and biomass production under water stress conditions. Zinc deficiency reduces plant tolerance to water stress and decreases biomass production (Khan *et al.,* 2004). Boron is involved in phosphorus metabolism and water relations in plants (Nason and Elroy, 1963). Efficient transport of boron through the xylem is essential for proper development of actively growing tissues such as broccoli heads (Shelp *et al.,* 1995).

In unmulched plots, increased transpiration likely disrupted xylem continuity and reduced boron transport to apical meristems, resulting in poor head development and lower water use efficiency. On the other hand, mulched plots with adequate zinc and boron supply maintained better soil moisture and reduced transpiration, thereby improving xylem transport, head development and water use efficiency.

The findings of the present investigation are in agreement with the results reported by Sarkar *et al.,* (2007) in yellow sarson, Rana (2009) and Lopez-Urrea *et al.,* (2009) in broccoli, and Prasad *et al.,* (2014) in French bean.

In conclusion, the study clearly demonstrated that mulching and micronutrient application significantly influenced water use and water use efficiency in broccoli. Application of paddy straw mulch @ 7 t ha^{-1} effectively conserved soil moisture and reduced consumptive water use. Foliar application of Zn @ 1% + B @ 0.5% further improved water use efficiency.

The combined application of paddy straw mulch with zinc and boron proved most effective in minimizing water use and maximizing water use efficiency in broccoli under rain fed conditions.



M_1 - Paddy straw mulch (PM)-7 t.ha^{-1} M_2 - Water hyacinth mulch (WHM)-7 t.ha^{-1} M_3 - No mulch (NM).

mn_1- Zn $_0$(0.00 %)+ B_0 (0.00 %),mn_2 - Zn $_1$ (0.5 %) + B_0(0.00 %),mn_3- Zn $_2$ (1 %) +B_0(0.00 %),mn_4- Zn $_0$ (0.00 %)+B_1 (0.5 %),mn_5- Zn $_1$ (0.5 %) + B_1 (0.5 %),mn_6- Zn $_2$ (1 %) + B_1 (0.5 %),mn_7- Zn $_0$(0.00 %)+B_2 (1 %),mn_8- Zn $_1$ (0.5 %) + B_2(1 %),mn_9- Zn $_2$ (1 %) + B_2 (1 %)

M_1mn_1- PM +Zn $_0$(0.00 %)+ B_0 (0.00 %),M_1mn_2 – PM +Zn $_1$ (0.5 %) + B_0(0.00 %), M_1mn_3- PM +Zn $_2$ (1 %) +B_0(0.00 %), M1mn$_4$- PM +Zn $_0$ (0.00 %)+B_1 (0.5 %), M_1mn_5- PM+ Zn $_1$ (0.5 %) + B_1 (0.5 %), M_1mn_6- PM +Zn $_2$ (1 %) + B_1 (0.5 %), M_1mn_7- PM+ Zn $_0$(0.00 %)+B_2 (1 %), M_1mn_8- PM+ Zn $_1$ (0.5 %) + B_2(1 %), M_1mn_9- PM +Zn $_2$ (1 %) + Bo$_2$ (1 %). M_2mn_1- WHM +Zn $_0$(0.00 %)+ B_0 (0.00 %), M_2mn_2 - WHM+ Zn $_1$ (0.5 %) + B_0(0.00 %), M_2mn_3- WHM +Zn $_2$ (1 %) +B_0(0.00 %), M_2mn_4- WHM +Zn $_0$ (0.00 %)+B_1 (0.5 %), M_2mn_5- Zn $_1$ (0.5 %) + B_1 (0.5 %), M_2mn_6- Zn $_2$ (1 %) + B_1 (0.5 %), M_2mn_7- Zn $_0$(0.00 %)+B_2 (1 %), M_2mn_8- Zn $_1$ (0.5 %) + B_2(1 %), M_2mn_9- WHM +Zn $_2$ (1 %) + B_2 (1 %). M_3mn_1- NM +Zn $_0$(0.00 %)+ B_0 (0.00 %), M_3mn_2– NM +Zn $_1$ (0.5 %) + B_0(0.00 %), M_3mn_3- NM +Zn $_2$ (1 %) +B_0(0.00 %), M_3mn_4- NM +Zn $_0$ (0.00 %)+B_1 (0.5 %), M_3mn_5- NM+Zn $_1$ (0.5 %) + B_1 (0.5 %), M_3mn_6- NM +Zn $_2$ (1 %) + B_1 (0.5 %), M_3mn_7- NM +Zn $_0$(0.00 %)+B_2 (1 %), M_3mn_8- NM +Zn $_1$ (0.5 %) + B_2(1 %), M_3mn_9- NM+ Zn $_2$ (1 %) + B_2 (1 %).

Conflict of interest

The authors declare that they have no conflict of interest

Declaration of competing interest

The authors declare that they have no potential competing financial interests

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