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ENHANCING CROP PRODUCTION BY ENHANCING WATER USE EFFICIENCY -A REVIEW

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ABSTRACT

Agriculture is the predominant user (75-80%) of the available fresh water resources in many parts of the world. As water resources shrinks and competition from other sectors grows, agriculture faces dual challenges: to produce more food with less water and to prevent the deterioration of water quality through contamination with soil runoff, nutrients and agrochemicals. Water use efficiency by crops can be enhanced by selection of crop, variety, Agronomic practices like time of sowing, method of sowing/planting, seed rate, plant population, interculture, fertilizer and irrigation, intercropping should be evaluated with the irrigation levels for high water use efficiency and economic yield of crop. Optimum time of sowing/planting, seed rate, plant population, interculture, herbicide application, fertilizer facilitate better growth and development which resulted in higher crop yield and water use efficiency. Conservation tillage practices like zero tillage; reduced tillage/minimum tillage utilizes more judiciously the plant available water than the conventional tillage when the other factors are similar.

Keywords:

WUE, Agronomic practices, Crops.

INTRODUCTION

Water is the most crucial input for agricultural production. Globally, agriculture accounts for more than 80% of all freshwater used by humans, most of that is for crop production (Morison *et al*., 2008). Currently most of the water used to grow crops is derived from rainfed soil moisture, with non-irrigated agriculture accounting for about 60% of production in developing countries. Though irrigation provides only 10% of agricultural water use and covers just around 20% of the cropland, it can vastly increase crop yields, improve food security and contribute about 40% of total food production since productivity of irrigated land is almost three times higher than that of rainfed land. The Food and Agriculture Organization has predicted a net expansion of irrigated land of about 45 million hectares in 93 developing countries (for a total of 242 million hectares in 2030) and projected that water withdrawals by the agriculture sector will increase by about 14% during 2000 – 2030 to meet food demand (FAO, 2006).

Agriculture sector in India has been and is likely to remain the major consumer of water but the share of water allocated to irrigation is likely to decrease by 10 – 15 per cent in the next two decades. Current use efficiency or

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productivity of irrigation water is so low that most, if not all, of our future water needs could be met by increased productivity or efficiency alone, without development of additional water resources. Improving water use efficiency by 40% on rainfed and irrigated lands would be required to counterbalance the need for additional withdrawals for irrigation over the next 25 years to meet the additional demand for food. Growing more crop per drop of water use is the key to mitigating the water crisis, and this is a big challenge to many countries.

2. Water use efficiency:-

Water use efficiency (WUE) is a broad concept that can be defined in many ways. For farmers and land managers, WUE is the yield of harvested crop product achieved from the water available to the crop through rainfall, irrigation and the contribution of soil water storage.

Water use efficiency denotes the production of per unit of water used by the crop or weight of produce per unit weight of water over a unit area. The water utilization by the crop is generally described in terms of WUE (kg/ha mm or g/ha cm). It can be expressed in two ways:

(a) Crop water use Efficiency:- It is the ratio of crop yield (Y) to the sum of the amount of water taken up and used by the crop in growth, transpired through foliage and evaporated directly from the soil surface or consumptively used (CU) (Molden, 1997; Teixeira *et al.*, 2009).

$$\boxed{\textbf{Crop WUE= Y/ET or CU}}$$

Where, Y= yield (Kg/ha)
ET= Evapotranpiration (mm, cm)
CU= Consumptive use

(b)Field Water use Efficiency:- It is the ratio of crop yield (Y) to the total amount of water used in the field. It can be shown as follows:

$$\boxed{\textbf{Field WUE= Y/ET or CU}}$$

Where, Y= yield (Kg/ha)
WR= Water Requirement (mm, cm)

For farmers, WUE is the yield of harvested crop product achieved from the water available through rainfall, irrigation and soil water storage. Improving WUE in agriculture will require an increase in crop water productivity (an increase in marketable crop yield per unit of water removed by plant) and a reduction in water losses from the crop root zone. The amount of water required for food production depends on the quantity of agricultural commodities produced. For example, the production of 1 kg beef would require 14 times more water than for 1 kg of wheat grain (Singh *et al.*, 2010).

2.1 WUE of Major Crops in India

Range and average values of water-use efficiency of selected crops in India are presented in Table 1. Among the foodgrain crops, WUE of wheat, maize, sorghum and pearl millet are much higher than that of rice. Among the legume crops, chickpea, lentil and kidney bean were more efficient user of water than pigeonpea, greengram and blackgram. Among the oilseed crops, WUE of sesame is much lower than that of soybean, mustard, groundnut, sunflower and linseed. Of the two important cash crops, WUE of sugarcane is much higher than that of cotton. Among three important vegetable crops, cauliflower is more efficient user than tomato. The WUE of tomato is higher than that of brinjal.

2.2 Factors Affecting WUE :-

I Climatic Conditions: - Plant transpiration and soil evaporation are dependent upon the temperature, wind velocity, relative humidity, sunshine hours and rainfall of a particular area. Higher temperature and wind velocity increases the ET thereby reducing WUE. (Prihar *et al*., 2000). Increased availability of light to plants increases photosynthesis resulting in greater production which consequently increases WUE of crops.

II Nature of crops and Variety:-

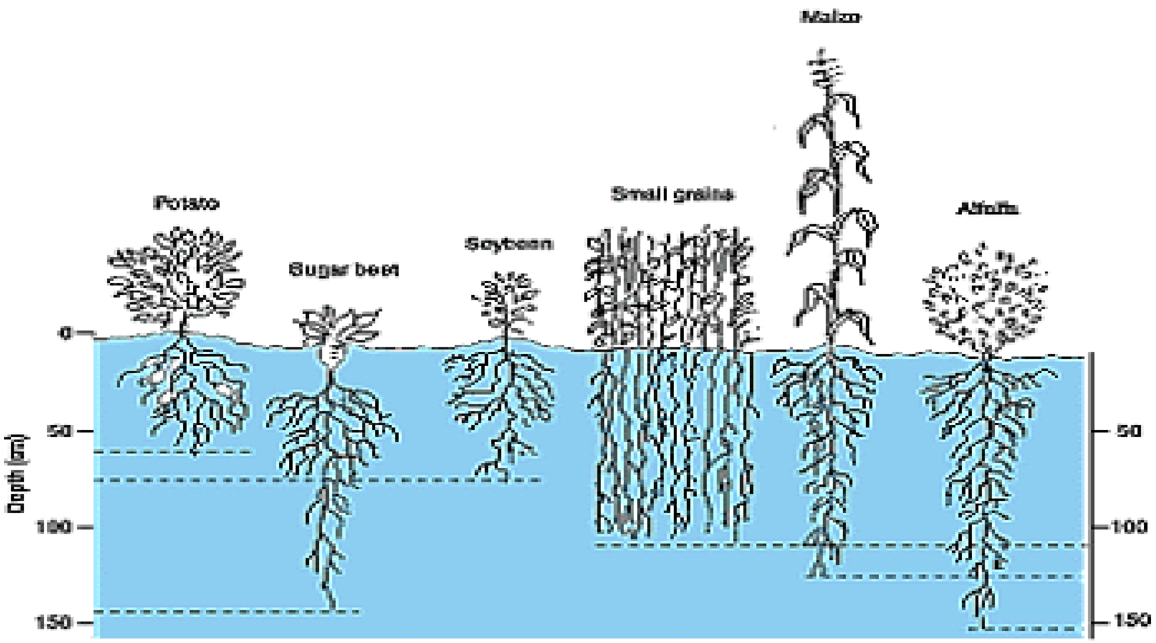
- Crops with higher canopies have greater growth and consequently higher photosynthesis which results in greater yield and higher photosynthesis which results in greater WUE.

- Plants with shallow and less developed roots are able to absorb less water and fertilizers resulting in their growth production. Consequently WUE is reduced.

- Crops belonging to C_3 group like wheat, barley, oats, pulses, and oilseed have less WUE because they have respiration in the presence of light (photorespiration) which results in lesser production but crops belonging to the C_4 group like Sugarcane, maize and sorghum have very little or no respiration in the presence of light which results in greater WUE and hence greater production.

Table 1. Water use efficiency of selected food grain crops grown in India.

Crop	No. of Observations	WUE Range (kg m^3)	Average WUE (kg m^3)
CEREALS			
Rice	6	0.30-0.54	**0.54**
Wheat	23	0.58-2.25	**1.24**
Maize	10	0.49-1.63	**0.91**
Sorghum	7	0.56-1.43	**0.88**
Pearlmillet	4	0.41-0.70	**0.54**
PULSES			
Chickpea	8	0.40-4.02	**1.60**
Lentil	6	0.39-2.43	**1.05**
Green gram	4	0.37-0.50	**0.44**
Pigeon pea	3	0.27-0.72	**0.46**
Black gram	2	0.25-0.31	**0.28**
Kidney bean	2	0.55-0.79	**0.67**
OILSEED CROPS			
Groundnut	7	0.20-1.11	**0.50**
Mustard	3	0.41-0.98	**0.67**
Sunflower	8	0.16-0.93	**0.59**
Sesame	2	0.36-0.36	**0.36**
Linseed	4	0.15-.93	**0.53**
Soybean	3	0.35-1.04	**0.60**
VEGETABLE CROPS			
Sugarcane	9	3.25-7.83	**4.68**
Cotton	8	0.17-0.40	**0.26**
Cauliflower	7	3.25-7.83*	**59.06***
Tomato	7	2.34-15.34*	**6.80***
Brinjal	6	0.26-.89*	**0.50***



2.3 Improving Water Use Efficiency:-

Agriculture sector in India has been and is likely to remain the major consumer of water but the share of water allocated to irrigation is likely to decrease by 10 – 15 per cent in the next two decades. Being a ratio, WUE is influenced by changes in both the nominator and denominator. The nominator is the crop yield (Y) which depends on such factors that affect gains in the form of dry matter production and losses due to disease, pests and other environmental factors. It means that WUE can be increased by genetic, environmental and cultural manipulation of crops. Under denominator (water supply) also subjected to manipulation and thus WUE can be increased by controlling water supply to crops. Any factor that increases yield will increase water use efficiency. Likewise any factor reducing evapo-transpiration that has no seriously deleterious effect on yield will increase water use efficiency

2.3.1 Agronomic Practices:-

Water use efficiency by crops can be enhanced by selection of crop, variety, agronomic practices like time of sowing, method of sowing/planting, seed rate, plant population, interculture, fertilizer and irrigation, intercropping moisture conservation practices as mulching, transpiration suppressants, moisture stress and vegetative barriers based on available water and increasing seasonal evapotranspiration.

(1)Varieties

The yields and water use efficiency of cultivars/hybrids of crops differed significantly. Those varieties/hybrids produced more than the water use should be grown under the limited water areas to increase the water productivity per unit area. Shivani et al. (2001, 2003) and Behera et al (2002) reported that wheat cultivars HUW 234 and Lok 1 had higher water use efficiency. Similarly, Chand and Bhan (2002) reported that Varsha sorghum was distinctly superior in water use efficiency in terms of grain production as well as dry matter production to CSV 13 and CSV 15. Similar findings were also reported by Singh et al. (2004) in chickpea of genotype Avarodhi, Awasthi et al. (2007) and Panda et al. (2004) Indian mustard varieties of Vaibhav and SEJ 2, Kumar et al. (2003) and Rathore et al. (2008) in pearlmillet hybrid of HHB 67-2, HHB 94 and HHB 117, Hooda et al. (1999) in field pea variety of HFP-8712, Patel et al. (2008) in cowpea variety of GC 4, respectively. Similar observations were also reported in summer moong varieties by Soni and Gupta (1999). It shows that the variety/hybrid should be evaluated for water use efficiency before to release in particular area according to the availability of water.

(2) Seeds Rate and Plant Population:-

Soil water evaporation is reduced with higher planting density. The desirable plant density which could be supported by available moisture up to production of economic part and not initial biomass only is recommended for these situations. Pandey *et al* (1988) observed that higher plant density (2,00,000 plants/ha) of rainfed pearlmillet gave higher consumptive use, rate of moisture use and water use efficiency as compared to the lower plant density of 1,00,000 plants/ha, owing to larger crop canopy. In spite of the higher consumptive use, the higher WUE under higher plant density could be attributed to the beneficial effect of increased evapo-transpiration on yield. Singh et al. (2003) reported that water use efficiency of wheat was higher at higher population density (15 cm, 205 kg seed/ha) than low population density (22 cm, 140 kg seed /ha).

(3) Sowing Time :-

The crop shown at proper time have greater production and hence higher WUE because timely sowing ensures proper temperature and other soil physical condition favouring optimum growth of crops. For the dwarf varieties of wheat, best sowing time considered later than the dates recommended for the late maturity tall varieties. Early as well as late sowing adversely affect the yield of crop and in poor WUE (Singh *et al*., 1988). ET demand of June 1transplanted rice is 620 mm against 520 mm for June 21 transplanted crop. Similarly, January-sown sunflower matures earlier than February sown crop, and requires less water leading to higher WUE (Hira, 2004).

(4) Depth of Sowing:-

Depth of sowing is an important factor as it affects seedling emergence, vigour and finally the yield. Seeds sown near the surface suffer from lack of moisture as soil dry out quickly by evaporation deep sown seeds take longer time to emergence and seedling are weak resulting in poor yields and ultimately in lower WUE.

(5) Method of Planting:-

Compared to broadcasting method of sowing, line sowing of crops have greater utilization and absorption of nutrients, water and light resulting in higher productivity and WUE. Planting crop on raised beds is a practice for increasing water use efficiency. The crop is sown with drill or planted on beds and water is applied in furrows. The comparable or higher yields are obtained with saving of about 25-30 percent water. This had been practiced in different crops like wheat, mustard, soybean and rice. Kaur (2006) reported that water use efficiency of wheat planted on beds was highest followed by conventional and zero tillage. Similar results reported by Kaur (2003) in normal sown crop, Parihar (2004) in late sown wheat, Ali and Ehsanullah (2007) in cotton, Zhang *et.al.* (2007) in winter wheat, Idnani and Gautam (2008) in summer greengram and Mahey et al. (2008) in soybean.

(6) Fertilizers

Fertilizer use can also have a very marked effect on crop yield and water use efficiency. Nitrogen, phosphorus, combination of chemical fertilizer with organic fertilizer or chemical fertilizer with biofertilizer has been shown to increase growth and development in both dry and irrigated areas. Kumar et al. (2000) reported that there was a progressive increase in water use efficiency of summer groundnut with increased level of fertilizer application and it was recorded to be higher with the use of organic and inorganic sources of fertilizer. Similar results were reported by Rathore et al. (2008) in pearlmillet. Kumar et al. (2003) reported that increasing levels of N from 0 to 150 kg/ha application markedly improved the water use efficiency of pearlmillet. Tetarwal and Rana (2006) reported that the highest water use efficiency, consumptive use and rate of moisture use were recorded with 80 kg N + 40 kg P_2O_5/ha, followed by 40 kg N + 20 kg P_2O_5/ha and the control**.** Patil and Sheelavantar (2000) reported that application of nitrogen increased the yield, water use efficiency and yield component of sorghum. Ghosh et al. (2003) reported that application of 75 % NPK and poultry manure 1.5 t/ha recorded the highest water use efficiency of rainfed sorghum.

(7) Inoculation

Inoculation can have a very marked effect on consumptive use and water use efficiency of legume crops. Singh et al. (2004) reported that inoculation of chickpea with Rhizobium + phosphate-solubilizing bacteria (PSB) significantly increased the consumptive use and water use efficiency over the single inoculation of Rhizobium or PSB and no inoculation, however, single inoculation with Rhizobium or PSB being at par, were significantly superior over control.

(8) Irrigation:-

When irrigation is considered, water losses also include the mismanagement of irrigation water from its source to the crop roots. Generally more than 50% of irrigation water is lost at the farm level. At the watershed level, however, it may be less due to possible recoveries from the subsoil and groundwater. The increase in water use efficiency with increase in irrigation level might be due to greater grain yield. Kibe and Singh (2003) reported that water use efficiency of wheat was the maximum with 2 irrigations given at crown root initiation stage and flowering stages in the first season and with one irrigation given at crown root initiation stage in the second season, followed by no post-sowing treatment. Behera et al (2002) in Madhya Pradesh reported that maximum water use efficiency of wheat was obtained when one irrigation applied at late jointing stage.

(9)Use of Mulches/Vegetative Barriers:-

Moisture conservation practices like straw mulch, straw + kaolin and polyethylene mulching are reducing weeds dry matter and weed density which resulted in enhancing crop yield and water use efficiency in rainfed areas. Vegetative barriers play significant role to increase the yields than that of water used by the crop. Chand and Bhan, (2002) reported that water use efficiency of sorghum was appreciably improved due to different vegetative barriers over control.

(10) Intercropping:-

Intercropping is a practice to have an opportunity to diversify cropping system by making the multiple land use possible utilizes water and other resources more effectively and also provides a cover against the failure of one crop particularly under the rainfed situations. Higher water use efficiency has been reported for maize-soybean and maize mungbean (De and Singh, 1981), maize-cowpea (Hulugalle and Lal 1986), Maize + potato (Bharati et.al. 2007), pearlmillet + greengram and pearlmillet + cowpea (Goswami et al. 2002) intercrops in relation to their respective monocrops.

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