JOURNAL OF PURE AND APPLIED MICROBIOLOGY, Dec. 2015. Vol. 9(4), p. 3109-3114

Influence of Irrigation Schedules and Nutrient Sources on Yield, Quality, Water Use and Water Productivity of Turmeric under Alluvial Soils of West Bengal

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(Received: 14 June 2015; accepted: 13 August 2015)

A field experiment was conducted at the Central Research Farm in the experimental field of AICRP on Water Management, BCKV, Gayeshpur, West Bengal, India, during 2011 and 2012 to assess the different irrigation and nutrition schedules on yield and water productivity of turmeric (*Curcuma Longa* L). The trial was laid out in a split-plot design with four irrigation schedules (I_1 = 0.6 IW/CPE, I_2 = 0.9 IW/CPE, I_3 = 1.2 IW/CPE and I_4 = rainfed) in main-plots and three nutrient sources (N_1 = 100 % inorganic, N_2 = 75 % inorganic + 25 % FYM and N_3 = 50 % inorganic + 25 % FYM + 25 % vermicompost) in sub-plots with three replications. The results significantly showed that mean highest value of fresh rhizome yield (23.90 kg ha^{-1}), qualitative yield (9.86% oleoresin, 4.47% curcumin and 5.05% oil content, respectively) and water productivity (54.9 kg ha^{-1} mm^{-1}) was obtained with irrigation schedule at 0.9 IW/CPE ratio, whereas the lowest fresh rhizome yield and water productivity of 15.25 kg ha^{-1} and 35.0 kg ha^{-1} mm^{-1} was recorded under rainfed condition, respectively. Among the nutrient sources at 50 % inorganic + 25 % FYM + 25 % vermicompost (N_3) was registered mean highest value of fresh rhizome yield (21.86 kg ha^{-1}), qualitative yield (9.41% oleresin, 4.45% curcumin and 4.89% oil content, respectively) and water productivity (54.9 kg ha^{-1} mm^{-1}) over the nutrient sources of 100 % inorganic (N_1) and 75 % inorganic + 25 % FYM (N_2). The interaction between irrigation schedules and nutrient sources revealed that the maximum fresh rhizome yield (25.71 kg ha^{-1}) was demonstrated under (I_2N_3) treatment combinations.

Key words: Turmeric; Irrigation schedule; Nutrient source; Yield; Quality; Water productivity.

Turmeric is one of the most important spice and medicinal crop grown extensively throughout the tropical and sub-tropical parts of the country. It is third important spice crop grown in India since ancient times and India enjoys monopoly in the production of turmeric[1]. In India, turmeric grown in an area of 181, 000 hectare with a production of 890,000 tonnes contributing to nearly 78 per cent of the world production during 2009-2010[2]. Turmeric can be grown in a wide variety of soil but it prefers to grow in light textured soil under shadow place[3]. In the Indo-Gangetic alluvial soils of West Bengal, the crop has immense potential in increasing productivity and yield sustainability. However, limited availability of irrigation water during the dry season is a major constraint in increasing area under turmeric cultivation. Even the unscientific water management practices coupled with lack of proper water saving

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technology can lead to the reduction in crop yield. The minimum water loss and higher yield per unit water was possible only if irrigation water applied through improve methods. The purpose of irrigation scheduling is to determine the exact amount of water apply to the field and the exact timing for application[4]. The importance of irrigation scheduling is based on the ET value[5]. The information consider on feasibility of irrigation and nutrient application as compared to straight cultivation on yield and water productivity of turmeric in this region. In this backdrop, it is thought worthwhile to develop an appropriate irrigation and nutrient schedules through IW: CPE ratio vis-à-vis rainfed and nutrient schedules on the yield and water productivity of turmeric in the Gangetic alluvial soils of West Bengal.

MATERIALS AND METHODS

A field experiment was conducted during 2011 and 2012 at the Gangetic alluvial soils of West Bengal, India to assess the different irrigation schedules and nutrient sources on growth and yield of turmeric. The site lies at 23°582 N latitude, 89° 312 E longitude and altitude 9.75 m above mean sea level. The Research Farm is situated in the tropical hot sub-humid climatic zone of eastern India. Normal annual rainfall is 1650 mm and 85% of it received during June 3rd week to September last week. January is the coldest month with a normal mean temperature value ranges from 15.5 to 21.3 °C. The atmospheric normal mean temperature begins to rise towards the end of February and reaching maximum (27.6–31.7 °C) during May. The normal mean relative humidity remains high (82–95%) during June to October and is at its lowest level (70%) in February. The soil is sandy loam in texture (Fluvaqent) with pH 6.7, EC 0.39 dSm^{-1} and organic carbon 5.8 g kg^{-1}. The available nitrogen, phosphorous and potassium were 118.0, 17.8 and 124.3 kg ha^{-1}, respectively. The trial was laid out in a split-plot design with four irrigation schedules (I_1 = 0.6 IW/CPE, I_2 = 0.9 IW/CPE, I_3 = 1.2 IW/CPE and I_4 = rainfed) in main-plots and three nutrient sources (N_1 = 100 % inorganic, N_2 = 75 % inorganic + 25 % FYM and N_3 = 50 % inorganic + 25 % FYM + 25 % vermicompost) in sub-plots with three replications. The cultivar *cv.* Suguna was planted on 2nd week of April at a spacing of 30 cm x 20 cm and was harvested on last week of November in each year. The recommended dose of fertilizers for the crop was 150:75:150 NPK kg ha^{-1}. Irrigation scheduling was based on IW/CPE ratio approach with 50 mm depth of water applied in each irrigation. Each irrigation water (IW) was 50 mm depth as measured with a Parshall flume and cumulative pan evaporation (CPE) was monitored from a standard USWB class A pan evaporimeter installed in the research station. Soil moisture conditions in the experimental field were measured by gravimetric method taking soil samples by soil augar from depths at 15 cm increments i.e. 0 to 15 cm, 16 to 30cm, 31 to 45cm and 46 to 60cm depths. Field moisture status was monitored at plantation, before and after each irrigation and at harvest. Rain water that is retained in the root zone and used by plants was considered as effective rainfall[6]. Evapotranspiration (ETc) during the entire cropping period (sowing to harvest) from the turmeric crop field was calculated by using the ûeld water balance equation[7]:

$$ETc = I + P \pm \Delta SW - Dp - R \qquad ...(1)$$

where, I is the amount of irrigation water applied (mm),

P is the precipitation (mm),

ΔSW is change the soil water content (mm) in the 0.60 m soil profile,

Dp is the deep percolation (mm), and

R is the amount of runoff (mm).

Since the amount of irrigation water was controlled, runoff was assumed to be zero. Monitoring soil water content in the experimental plots revealed that Dp was negligible below 0.60 m. The water utilized by the crop is generally expressed in terms of 'water use efficiency' (WUE). It is the ratio of crop yield to the amount of water depleted by the crop in the process of evapotranspiration. In other words, water use efficiency (WUE) is the yield per unit area of land per unit depth of water used by the crop and is expressed as kg ha^{-1} mm-[1]. According to Kang et al. the water use efficiency (WUE, kg ha^{-1} mm^{-1}) was calculated as[7]:

$$WUE = Y/ETc \qquad ... (2)$$

where, Y= rhizome yield (kg ha^{-1}) and

ETc = crop evapotranspiration (mm).

The essential oil (% v/w) content was determined using Clevenger's apparatus which was given by Thimmaiah[8]. Curcumin content (%) was estimated as per the procedure of Sadasivam and Manickam[9]. Oleoresin content was observed by refluxing known weight of turmeric powder in acetone at 60°C for 5 hr using Soxhlet extraction apparatus[10]. The data relating to yield and quality were statistically analysis as per Gomez and Gomez[11].

RESULTS AND DISCUSSION

Yield

Irrigation schedule at 0.9 IW/CPE (I_2), irrespectively of nutrient schedules, recorded significantly the higher fresh rhizome yield over rainfed and other irrigation schedules in all the years and their average values (Fig. 1). Irrigation schedule at 0.9 IW/CPE (I_2), on an average, increased the rhizome yield by 15, 2, and 36 % over irrigation schedules at 0.6 IW/CPE (I_1), 1.2 IW/CPE (I_3) and rainfed condition, respectively. This variation in yields under rainfed and irrigation system was mainly due to the differences in wetting patterns, water distributions in soil and relative water use by crops. Increase in fresh rhizome yield under right management of irrigation schedules[12,13]. Among different nutrient sources were also observed to be significant on fresh rhizome yield

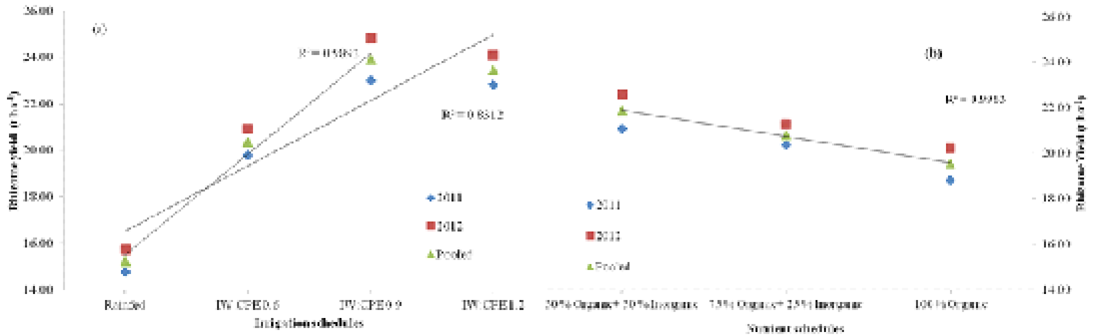

Fig. 1. Effect of different irrigation (a) and nutrient (b) schedules on rhizome yield of turmeric

Table 1. Effect of irrigation schedules on water use and water productivity by turmeric (pooled over 2 year)

Treatment	Soil profile contribution (mm)	Effective rainfall (mm)	Irrigation water (mm)
I_1 (at IW/CPE 0.6)	15.5	228.5	175.0
I_2 (at IW/CPE 0.9)	15.4	228.5	225.0
I_3 (at IW/CPE 1.2)	15.9	228.5	275.0
I_4 (at rainfed)	14.2	228.5	-

Table 2. Interaction effect of irrigation and nutrient schedules on rhizome yield of turmeric (pooled over 2 year)

Treatments	Rhizome yield (t/ha)			
	N_1 (100 % inorganic)	N_2 (75 % inorganic + 25 % FYM)	N_3 (50 % inorganic + 50 % vermicompost)	Mean
I_1 (at IW/CPE 0.6)	19.70	20.35	21.02	20.36
I_2 (at IW/CPE 0.9)	21.52	24.48	25.71	23.90
I_3 (at IW/CPE 1.2)	22.47	23.22	24.65	23.45
I_4 (at rainfed)	14.45	15.23	16.06	15.25
Mean	19.54	20.82	21.86	-
CD at 5 %	I 0.49	N 0.22	I x N 0.65	-

of turmeric. The maximum fresh rhizome yield (Fig. 1) was observed with N_3 (50 % RDF integrating with 25 % FYM + 25 % vermicompost) and minimum fresh rhizome yield was recorded with N_1 (100 % RDF). These results corroborated to the finding of Rathod et al. who observed that vegetative growth and rhizome yield parameters increased with increasing nitrogen rate and greater fresh rhizome yield (160 kg N ha^{-1}) was recorded[14]. The significant increase in fresh rhizome yield is attributed to adequate moisture in the rhizosphere resulting in better uptake of nutrients with increased plant growth, yield and yield components. Correlation between Irrigation/nutrient schedule and fresh rhizome yield was shown that irrigation level was increased correction (0.9892) upto I_3 however irrigation level was increased, correlation decreased. Whereas, nutrient schedule was obtained 0.9963 correlation factor. Different interaction levels among irrigation schedules and nutrient sources showed significant effect on fresh rhizome yield of turmeric (Table 2). Furthermost fresh rhizome yield (25.71 t ha^{-1} in pooled value) of turmeric crop was recorded with I_2N_3 followed by other treatment combinations. Significantly lower rhizome yield (14.45 t ha^{-}) was noticed under I_4N_1 treatment combinations. The stumpy rhizome yield in rainfed crop may be due to water stress during rhizome initiation and rhizome bulking stage.

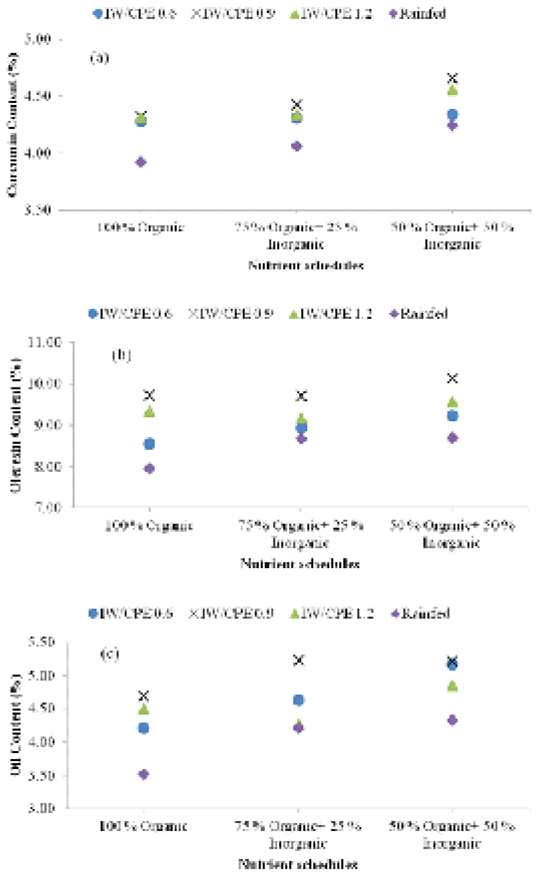

Fig. 2. Interaction effect of different irrigation (a) and nutrient (b) schedules on (a) Curcumin (%), (b) Oleresin (%) and (c) Oil (%) content in turmeric

Quality Attributes

The pooled data presented in (Fig 2), clearly revealed that the significant influenced of irrigation schedules and nutritional levels on oleresin, curcumin and oil content of turmeric. Among different irrigation levels, 0.9 IW: CPE (I_2) produced good quality of turmeric rhizomes with superior content of oleresin, curcumin and oil (9.86, 4.47 and 5.05 %, respectively) content which is statistically at par all the treatment. The worse content of oleresin, curcumin and oil (8.45, 4.08 and 4.02 %, respectively) was obtained under I_4 (rainfed) treatment. The qualitative yield of turmeric was also statistically influenced by different nutritional sources. The maximum oleresin, curcumin and oil content of turmeric (9.41, 4.45 and 4.89 %, respectively) were established with N_3 (50% RDF + 25% FYM + 25% VC) treatment.

Table 3. Effect of different levels of irrigation and nutrient sources on oleresin, curcumin and oil content of turmeric (pooled over 2 year)

Treatment	Oleresin (%)	Curcumin (%)	Oil (%)
Irrigation schedules			
I_1	8.91	4.31	4.67
I_2	9.86	4.47	5.05
I_3	9.36	4.41	4.54
I_4	8.45	4.08	4.02
SEm. (±)	0.17	0.04	0.23
CD at 5%	0.54	0.11	NS
Nutrient sources			
N_1	8.89	4.21	4.23
N_2	9.12	4.29	4.59
N_3	9.41	4.45	4.93
SEm. (±)	0.05	0.02	0.13
CD at 5%	0.14	0.05	0.38

Statistically (N_3) treatment was superior over all other treatment. I_2N_3 treatment combinations showed supreme consequence with respect to qualitative yield of turmeric rhizome.

Water Use and Water Productivity

Water productivity of the crop was measured as the ratio of fresh rhizome yield (RY) to crop evapotranspiration (ETc). During two consecutive cropping seasons of 2011 and 2012, average value of effective rainfall, soil water contribution from profile and depth of irrigation water applied are given in Table 1. Irrigation water applied at 0.6, 0.9 and 1.2 IW: CPE was 175, 225, and 275 mm, respectively to turmeric, whereas the corresponding without irrigation to a rainfed treatment. The average values soil profile moisture contributions were 15.5, 15.4 and 15.9 mm at 0.6, 0.9 and 1.2 of IW: CPE, respectively, while the figures for rainfed was 14.2 mm. Accordingly, the total water used by the crops on average values 418.9, 468.9 and 519.4 mm through irrigation schedules at 1.2 and 0.6 IW: CPE, respectively, and the corresponding figures for rainfed condition was 242.6 mm. Irrigation schedule at 0.9 IW: CPE registered the highest water productivity of 54.9 kg ha^{-1} mm^{-1} with compared to rainfed which exhibited water productivity of 35.0 kg ha^{-1} mm^{-1}. The corresponding values of water productivity for irrigation schedule at 1.2 IW: CPE and 0.6 IW: CPE were 53.9 kg ha^{-1} mm^{-1} and 46.7 kg11 ha^{-1} mm^{-1}, respectively (fig.3). The correlation coefficients of water use and water productivity, respectively, were found 0.9059 and 0.9898 at IW/CPE0.9 whereas cofficent with irrigation level upto I_3 then after

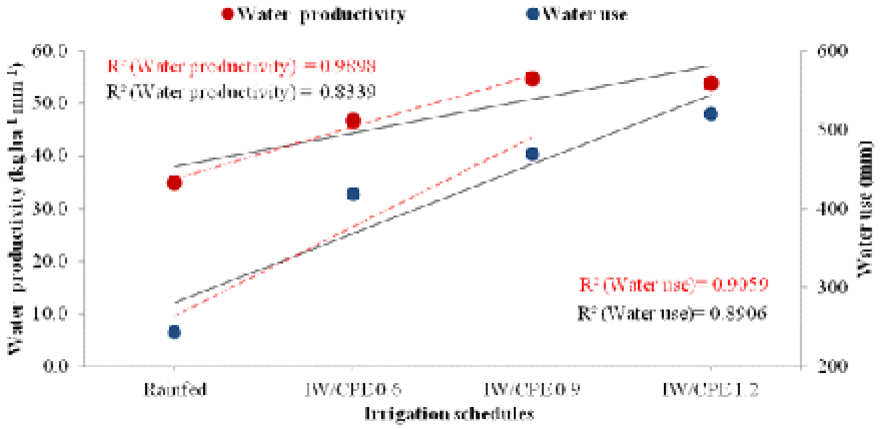

Fig. 3. Effect of different irrigation schedules on water use and water productivity on turmeric

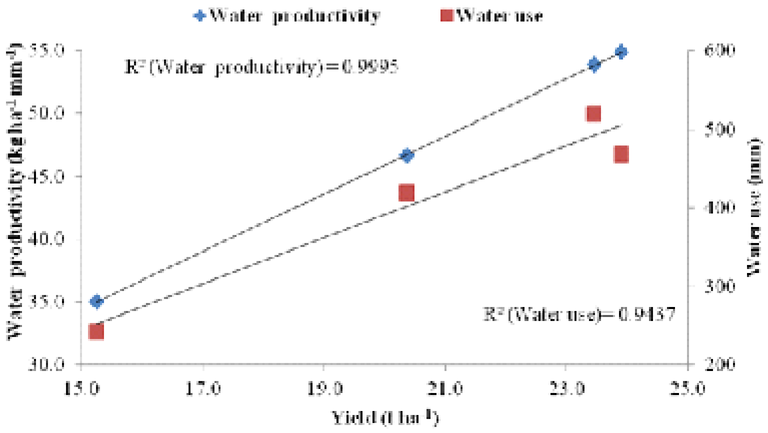

Fig. 4. Correlation cofficient between water use or water productivity and yield of turmeic

decreased. In between water productivity and yield, the correlation coefficient water found 1.00, whereas water use and yield got 0.9437 (fig. 4). It was cleared that the rate of water productivity was improved with increasing yield of crop. While, the rate of water use was not constantly increased, if crop yield increased. Thus the irrigation facilitated to decrease the soil moisture loses by way of evaporation and cloud more water in the subsurface soil profile for subsequent plant use. Maximum water productivity was obtained when irrigation water supply maintained at a high level around field capacity. The consumptive uses by crop under such conditions occur at a potential rate.

CONCLUSION

Thus, the results of the present study clearly established that significantly maximum yield and water productivity of turmeric were observed due to the main effects of irrigation schedule at 0.9 IW: CPE (I_2), nutrient schedule at 50 % RDF + 25 % FYM + 25 % vermicompost (N_3) and their interactions (I_2N_3). Under conditions of ample water supply, irrigation can be given at IW: CPE ratios of 0.9 or 1.2. Lower levels of irrigation resulted in plant stress which could be seen reflected in the yield. In order to achieve the highest water use efficiency, it is best to go for irrigation schedule at 0.9IW: CPE ratio. These results should help the precise planning and efficient management of irrigation for the crop in this region.

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