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RESPONSE OF IRRIGATION SCHEDULING AND FERTILITY LEVELS ON PRODUCTIVITY AND NUTRIENT UPTAKE OF JATROPHA (*JATROPHA CURCAS* L.)

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ABSTRACT

An experiment was conducted during 2009 and 2010 at seed production farm Achhaliya, ASPEE College of Horticulture & Forestry, Navsari Agricultural University, Navsari, Gujrat to study the effect of different irrigation scheduling and fertility levels on yield and nutrient uptake of *jatropha*. Experiment was laid out in split plot design with four irrigation scheduling in main plot *viz*. 0.4, 0.6, 0.8 and 1.0 IW/CPE ratio and four fertility levels in sub-plot *i.e*. control, 20:40:20, 40:80:40 and 60:120:60 g NPK/plant and replicated thrice. Results revealed that irrigation scheduling at 0.6 IW/CPE ratio recorded markedly higher shell (399 and 541 kg/ha) and seed yield (838 and 1148 kg/ha) compared to rest of treatment. Further, fertilization with 60:120:60 g NPK/plant recorded significantly higher shell (647 and 810 kg/ha) and seed nutrient yield (1409 and 1891) of the crop. However, NPK uptake through leaves, stem, shell and seed were found significantly higher with irrigation scheduling of 0.6 IW/CPE compared to 1.0, 0.8 and 0.4 IW/CPE ratio except N uptake of leaves at 270 DAP. Hence, *jatropha* should be grown with irrigation scheduling of 0.6 IW/CPE ratio along with fertilization of 60:120:60 g NPK/plant to get the maximum productivity and nutrient-use efficiency in South Gujarat.

INTRODUCTION

Biofuel is renewable and benign to environment and has showed a great potential in coping with worldwide energy crisis and the increasingly serious environmental problems (Anand *et al*., 2011). Increasing rate of depletion of fossil fuel leads people to think about alternative sources of energy (Navanita and Goswami, 2010). Many non-edible tree-born oil-seed species such as *Jatropha*, Karanj, Mahua and Sal *etc*. widely found in India. Among these, *Jatropha curcas* is recognized as the most potential species for bio-diesel production (Kumar, 2015). This crop has drawn the attention of researchers in recent years due to its emergence as a highly suitable feedstock plant for biodiesel production. It is a drought resistant, photo-insensitive perennial plant belonging to the family Euphorbiaceae is attracting increased interest as an important source of bio-diesel and can be grown under different land use systems (Kochhar *et al*., 2005). It can be easily propagated by seed/cuttings and starts bearing the fruits within 2-3 years, commercially exploited in 4-5 years and lasts for 50 years (Kumar *et al*., 2005). It is a multi-purpose shrub and is considered to have originated in Latin America but presently, it grows throughout the arid, semi-arid, tropical and sub-tropical region of the world. *Jatropha* plant produces seeds with an oil content of 30-38% and can be combusted as a fuel without being refined (Kumar *et al*., 2008).It burns with clear smoke-free flame, tested successfully as fuel for simple diesel engine. Seed oil can be easily processed to partially replace petroleum based diesel fuels. Press cake, which is a by-product, can be used as organic fertilizer and oil is having insecticidal properties as well. The use of this plant for large-scale bio-diesel production is of great interest with regard to solving the energy shortage, reducing carbon emission and increasing. Oil content of kernel, which can be transformed into bio-diesel fuel through esterification (Paramathma *et al*., 2006). The utilization of *Jatropha* oil as a fuel for diesel engine has tremendous scope, thus contributing to growing need of energy resources in the country (Reiger *et al*., 2011).

Productivity of *jatropha* can be boosted through the rational use of irrigation and fertilization (Kumar *et al*., 2016 a). Amount of stored soil moisture may not be adequate for higher yields in varied agro-climatic conditions for cultivation of jatropha though a drought tolerant crop (Kumar *et al*., 2016b). Amongst various factors responsible for lower yield, lack of irrigation facility, knowledge on water requirements and poor supply of nutrient by avoiding the use of inorganic fertilizers seems to be the main causes. The water used at critical growth periods is more important, when water supply is limited. Hence, the proper moisture balance needs to be maintained for satisfactory crop yield (Kumar *et al*., 2016c). *Jatropha* with its profuse branching after pruning and extensive root system have higher production potential and responsive to supplemental nutrients and irrigation (Kumar *et al*., 2016 a). The optimum levels of fertilization increases efficiency of irrigation water too (Kumar *et al*., 2016 a, b and c). However, it is essential to maintain the proper supply of moisture and nutrition levels to exploit the full potential of crops in terms of seed yield and nutrient uptake. Keeping the above facts in view, the present investigation was undertaken.

MATERIALS AND METHODS

Field investigation was conducted during 2009 and 2010 at seed production farm Achhalia, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, South Gujarat. Experimental site was located at 21^{0}47'21"N latitude and 73^{0}16'41" E longitude in tropical region, having an altitude 60 m above the mean sea level. Soil of the experimental plots was clayey in texture (sand: 17.65, silt: 32.45 and clay: 49.9%), low in available nitrogen (97.6 kg/ha), phosphorus (47.7 kg/ ha) and potassium (159.3kg/ha). Experiment was laid out in split-plot design with four irrigation schedules at critical growth stages *viz*. 0.4, 0.6, 0.8 and 1.0 IW/CPE ratio and four levels of fertilization i.e. control, 20:40:20, 40:80:40, and 60:120: 60 g NPK/plant and replicated thrice. Half doses of N and full doses P_2O_5 as well as K_2O were placed at 5 cm deep in soil around plants and remaining doses of N was applied in two equal split at 30 and 60 days after first application through urea, single super phosphate (SSP) and muriate of potash (MOP). Total amount of annual rainfall was received in 2009 and 2010 was 885.4 and 1184.5 mm, respectively. Maximum rainfall was recorded of 209.6 and 134.4 mm and 217 and 194 mm in the month of July and August of 2009 and 2010, respectively. Minimum and maximum temperature ranged from 12.1-39.40^{0}C and 12.34-46.80^{0}C in 2009 and 2010, respectively. The present study was conducted on 5 years old *Jatropha* plants and all plants selected were uniform in growth and size, planted at the spacing of 2.0 m x 2.0 m (2500 plants/ ha). Proper training and pruning of plants were performed at 75 cm height and other intercultural practices i.e. weeding and cleaning was undertaken whenever required. Chlorpyriphos was applied @ 10 ml/plant with irrigation water to protect the crops from termites. *Jatropha* fruits were harvested and allowed to sundry for 4-5 days at pucca floor, weighed and stored. Seeds yield was recorded after manually dehusked from har-vested fruits, dried, winnowed and kept in muslin cloth bag. Periodical samplings of leaves, stem, shell and seed from each treatment were taken to assess the nutrient content. To assess N, P and K content, representative samples were dried at 60^{0C} and stem at 102^{0C} after drying samples of stem, leaves, shell and kernel were ground up to 2 mm size separately and analyzed. Nitrogen content in the plant sample was determined by Kjeldahl method (Jackson 1973). To determine phosphorus and potassium contents, plant samples were digested in diacid (nitric acid + perchloric acid). Phosphorus was estimated by phospho-vanadomolybdate method using Barton's reagent as suggested by Jackson (1973), recording absorbance at 420 nm wavelength of yellow colour complex (phospho-vanado-molybdate heteropoly complex) formed due to the reaction of extracted plant orthophosphates with molybdate and vanadate, using spectro- photometer fitted with blue filter. Phosphorus content in the aliquot was estimated with the help of a standard curve prepared by using potassium dihydrogen orthophosphate (KH_2PO_4). Potassium content in digested samples was determined by flame photometer after making proper dilutions (Bhargava & Raghupati 1993). Nutrient uptake in leaf, stem, shell and seed was calculated by determining nutrient concentration in relation to their dry matter production. The replicated data were statistically analyzed to work out significance of treatment (Panse and Sukhatme, 1978).

RESULTS AND DISCUSSION

Effect on Seed and shell yield

Effect of irrigation scheduling on shell and seed yield of *jatropha* was found to be significant during both the years (Table 1). The highest shell yield of 399 and 541 kg/ha were recorded with 0.6 IW/CPE ratio, which was on a par with 0.8 and 1.0 IW/CPE ratio. The 0.6 IW/CPE ratios increase shell yield of 69.8 and 76.2 per cent compared to 0.4 IW/CPE ratio, respectively. Further, application of 0.6 IW/CPE ratio was found to be significantly superior and gave the highest seed yield of 838 and 1148 kg/ha, which was noted 94.4 and 97.6 per cent higher than 0.4 IW/CPE ratio in 2009 and 2010, respectively. This showed that increasing number of irrigation increased crop yield linearly up to 0.6 IW/CPE ratio but beyond that it

Table 1: Effect of irrigation scheduling and fertility levels on yield of *jatropha*

Treatment	Shell yield (kg/ha)		Seed yield (kg/ha)	
	2009	2010	2009	2010
Irrigation scheduling (IW/CPE ratio)				
0.4	235	307	431	581
0.6	399	541	838	1148
0.8	369	471	777	1081
1.0	359	425	726	1001
SEm ±	17	10	33	31
LSD (P=0.05)	59	36	113	107
Fertility level (g NPK/plant)				
Control	41	39	72	69
20 :40 :20	236	327	443	660
40 :80 :40	437	567	848	1191
60 :120 :60	647	810	1409	1891
SEm ±	13	13	28	40
LSD (P=0.05)	31	37	82	118

DBS = day before spray, DAS = days after spray; Each observation is an average of 3 sprays for aphids and two sprays for whiteflies

Table 2: Effect of irrigation schedules and fertility levels on N uptake (kg/ha) by leaf and stem of *jatropha*

Treatment	Leaf						Stem					
	2009			2010			2009			2010		
	90 DAP	180 DAP	270 DAS	90 DAP	180 DAP	270 DAS	90 DAP	180 DAP	270 DAS	90 DAP	180 DAP	270 DAS
Irrigation scheduling (IW/CPE ratio)												
0.4	19.59	32.41	3.77	30.53	47.90	5.26	21.81	30.89	42.57	35.62	45.70	59.06
0.6	25.06	45.99	3.99	41.11	66.05	5.50	34.34	47.82	67.50	56.81	68.07	85.69
0.8	24.49	41.40	3.96	38.21	62.90	5.23	32.46	45.19	61.83	52.37	63.49	80.41
1.0	23.60	39.42	3.87	36.55	57.90	5.07	31.53	43.57	59.76	47.32	60.64	74.57
SE ±	0.13	0.48	0.033	0.5	0.48	0.07	0.83	0.57	0.51	0.92	0.62	1.03
LSD (P = 0.05)	0.44	1.66	0.13	1.74	1.66	0.25	2.87	1.99	1.78	3.92	2.16	3.58
Fertility level (g NPK/plant)												
Control	12.90	22.78	3.35	21.95	34.22	4.89	15.40	23.14	33.40	26.51	36.24	47.46
20 :40 :20	17.81	28.58	3.69	28.26	47.37	5.02	21.18	29.76	40.20	34.91	45.56	57.21
40 :80 :40	24.64	40.96	3.92	38.42	61.29	5.22	32.58	44.47	60.48	50.31	61.45	74.05
60 :120 :60	37.39	66.89	4.54	57.79	92.86	5.91	50.59	70.11	97.57	80.39	94.65	121.00
SE ±	0.21	0.29	0.033	0.44	0.4	0.06	0.69	0.51	0.35	0.64	0.66	0.93
LSD (P = 0.05)	0.61	0.84	0.096	1.27	1.17	0.17	2.01	1.5	1.04	1.87	1.93	2.72

Table 3: Effect of irrigation schedules and fertility levels on nutrient uptake (NPK kg/ha) by shell and seed of *jatropha*

Treatment	N				P				K			
	Shell		Seed		Shell		Seed		Shell		Seed	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Irrigation scheduling (IW/CPE ratio)												
0.4	3.61	4.95	1.09	1.28	0.27	0.38	2.14	2.84	15.08	19.15	4.44	5.92
0.6	6.29	9.16	2.39	2.77	0.51	0.68	4.14	5.98	25.50	34.72	9.06	12.26
0.8	5.77	7.91	1.95	2.38	0.45	0.58	3.79	5.42	23.43	29.89	8.15	11.30
1.0	5.61	7.12	1.65	2.12	0.43	0.51	3.51	4.99	22.36	26.43	7.73	10.32
SE ±	0.25	0.17	0.08	0.07	0.020	0.014	0.16	0.16	1.09	0.59	0.32	0.33
LSD (P = 0.05)	0.86	0.60	0.28	0.25	0.069	0.047	0.55	0.54	3.80	2.04	1.12	1.13
Fertility level (g NPK/plant)												
Control	0.53	0.59	0.06	0.05	0.05	0.04	0.32	0.29	2.48	2.48	0.63	0.61
20 :40 :20	3.53	5.30	0.63	1.10	0.27	0.40	2.03	3.05	14.54	20.20	4.17	6.02
40 :80 :40	6.77	9.38	2.00	2.61	0.52	0.68	4.08	5.90	27.96	35.88	8.84	12.16
60 :120 :60	10.45	13.87	4.42	4.80	0.82	1.02	7.17	9.99	41.39	51.73	15.73	21.00
SE ±	0.21	0.21	0.07	0.10	0.014	0.016	0.14	0.21	0.83	0.74	0.29	0.43
LSD (P = 0.05)	0.62	0.62	0.22	0.28	0.045	0.045	0.40	0.60	2.41	2.17	0.86	1.25

was noted in declining trend. Which indicates that crop needs optimum level of water. These might be due to moisture deficit created adverse effect on floral bud initiation, flower development and fruits/pod formation, pod development and induced abscission of flowers and vegetative bud formation. Application of water at higher ratio lead to higher pod formation possibly due to improvement in growth and yield attributes with availability of sufficient moisture (Kumar 2016 a, b, c). Similar findings were also reported by Chamar (2008) in *jatropha*.

Application of increasing levels of fertilizer was found to be significant with respect to shell and seed yield of *jatropha* (Table 1). Among the levels of fertilizers, application of 60:120:60 g NPK/plant gave significantly highest shell (647 and 810 kg/ha) and seed yield (1409 and 1891 kg/ha) over rest of treatment. Increased dose of fertilizer i.e. 60:120:60 g NPK/plant, seed yield was enhanced by 66 and 59 per cent compared to 40:80:40 g NPK/plant and 218 and 187 per cent higher than 20:40:20 g NPK/plant, respectively in 2009 and 2010. Higher levels of fertilization resulted in rapid expansion of dark green colour foliage, which could intercept, utilize more incident light energy in production of food through process of photosynthesis and increased production of food required for plant growth and development and gave higher shell and seed yield (Kumar 2016 a, b, c). Increase in shell and seed yield of *jatropha* at higher level of fertilization was supported by Patil *et al.* (2006). Similar results were reported by Kalannavar and Angadi (2009) in *jatropha*.

Effect on nutrient uptake

Nitrogen uptake for leaf and stem was computed periodically at 90, 180 and 270 DAP leaves, stem, shell and seed (270 DAP) The N uptake by leaves, stem, shell and seed of *jatropha* were significantly influenced due to application of various irrigation schedules (Table 2&3). The irrigation schedules of 0.6 IW/CPE ratio maintained its superiority for N uptake but on a par with 0.8 IW/CPE. In all the cases, 0.4 IW/CPE ratio recorded significantly lower N uptake. Significantly highest values of N uptake by leaves (25.1and 41.1 kg/ha, 45.9 and 66.1 kg/ha and 3.99 and 5.5 kg/ha) recorded with irrigation schedule of 0.6 IW/CPE ratio in 2009 and 2010 at 90, 180 and 270 DAP, respectively. Maximum value of N uptake (3.99 and 5.5 kg/ha) was recorded at 0.6 IW/CPE ratio in 2009 and 2010, which was recorded on a with 0.8 and 1.0 IW/CPE ratio in 2009 and with 0.4 IW/CPE in 2010. Significantly highest value of N uptake in stem (34.34 and 56.8 kg/ha, 47.8 and 68.1 kg/ha and 67.5 and 85.69 kg/ha) were observed with 0.6 IW/CPE ratio at 90, 180 and 270 DAP during 2009 and 2010, respectively. Irrigation scheduling of 0.8 IW/CPE (32.46 kg/ha) and 0.8 IW/CPE ratio (31.53 kg/ha) was noted at par with 0.6 IW/CPE in 2009 at 90 DAP. Uptake of N by shell and seed of *jatropha* was influenced due to irrigation schedule. Significantly highest value (6.29 and 9.16 kg/ha) were observed with 0.6 IW/CPE ratio at 270 DAP in both the years, respectively. The 0.8 IW/CPE ratio (5.77 kg/ha) and 1.0 IW/CPE (5.61 kg/ha) were noted at par with 0.6 IW/CPE in 2009. Significantly highest value (2.39 and 2.77 kg/ha) were recorded at IW/CPE ratios 0.6 at 270 DAP, respectively. Periodical uptake of N, P and K through leaves, stem, seed and shell at final harvest (270DAP) were found significantly higher with 0.6 IW/CPE ratio except on N uptake of leaves at 270 DAP, where 0.8 IW/CPE was found significantly superior but at par with 0.6 IW/CPE. In most of the cases irrigation schedule 0.6 IW/CPE was found at par with 0.8 and 1.0 IW/CPE (N uptake by leaf, stem and shell at 90 DAP and 270 DAP in 2009, K_2O uptake leaf and shell at 270 DAP in 2009), 0.6 IW/CPE ratio was also observed at par with 0.8 IW/CPE ratio (P_2O_5 uptake leaf, shell and seed at 270DAP, K_2O uptake by stem at 180 DAP in 2009 and K_2O uptake by seed in 2009 and 2010).This may be due to availability and absorption of water and nutrient in optimum rate and consequently more biomass production and accumulation in different plant parts of *jatropha*. The results are supported by Azza *et al*. (2010) that increasing water supply increased significantly N, P and K uptake in shoots.

Application of fertilizer significantly increased N uptake by leaves at all the growth stages. Significantly highest value (37.39 and 57.79 kg/ha, 66.89 and 92.86 kg/ha and 4.54 and 5.91 kg/ha) were observed with fertilizer level of 60:120:60 g NPK/plant in 2009 and 2010 at 90, 180 and 270 DAP, respectively except control and 20:40:20 g NPK/plant were on a par at 90,180 and 270 DAP in 2010. It can be inferred that N uptake by stem increased significantly owing to fertilization at varying levels. Significantly highest value (50.5 and 80.3 kg/ha, 70.1 and 94.6 kg/ha and 97.5 and 121 kg/ha) were recorded with fertilizer level of 60:120:60 g NPK/plant in 2009 and 2010, respectively. Significantly increasing trend of N uptake was observed from control to 40:80:40 g NPK/plant in all the growth stages. N uptake by shell increased significantly owing to fertilization. At 270 DAP, significantly highest values (10.45 and 13.87 kg/ha) of N uptake was recorded with fertilization of 60:120:60 g NPK/plant. Significantly the highest value (4.42 and 4.80 kg/ha) for N uptake were recorded with fertilizer level of 60:120:60 g NPK/plant in 2009 and 2010, respectively. This might be due to more utilization of nutrients to perform other production functions. These findings are in agreement with those reported by Achten (2010) in *jatropha*. It is well established fact that with increase in levels of fertilization, uptake of nutrients increases and therefore, uptake of N, P and K by stover and seed yield increased. This indicates that higher rate of fertilization increased the availability of N, P and K in the soil, which lead to increase in uptake of N, P and K in seed and shell (Kalannavar and Angadi, 2009; Prajapati, 2007).

It may be concluded that *jatropha* should be grown with irrigation scheduling of 0.6 IW/CPE ratio along with fertilization of 60:120:60 g NPK/plant to get the maximum productivity and nutrient-use efficiency on clayey soil in South Gujarat.

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