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Effects of Fertilizer Application on Growth and Yield of *Jatropha curcas* L. in an Aeric Tropaquept of Eastern India

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Abstract

In recent years *Jatropha curcas* L. has emerged as a biofuel crop attracting considerable interest of the researchers. The seeds of the plant yield non-edible oil with properties that are well suited for production of biodiesel. However it is still considered a semi-wild plant and systematic crop improvement programmes need to be undertaken to exploit its full yield potential. The present study deals with agronomic trials pertaining to optimum requirements of N:P:K fertilizers for better economic returns. Field experiments were conducted between 2008 and 2009 at the research farm of IMMT, Bhubaneswar, India (20°40' North and 85°50' East) to evaluate the effect of N:P:K fertilizers on the yield attributing characters of *Jatropha*. Five-year-old standing crop plantation was treated with two levels of N (60 and 50 g/plant), P (80 and 100 g/plant) and K (75 and 60 g/plant), either alone or in combination. Analysis of the results revealed significant differences in growth as well as yield characteristics due to application of inorganic fertilizers. While maximum seed yield (427.21 kg/ha) was recorded in N_{60} treatment, the seed oil content varied significantly from 32.00% to 35.69% under various regimes of N:P:K applications. Treatment with $N_{50}P_{100}K_{60}$ and N_{60} resulted in consistent higher yield of seed oil. Based on the results of growth and yield attributes, application of N fertilizer proved to be beneficial for *Jatropha* under tropical agroclimatic conditions in an Aeric Tropaquept of eastern India.

Keywords: *Jatropha*, NPK, oil content, seed yield

Introduction

The demand for plant-based feedstock for biodiesel production has received much attention in recent years due to green energy policy *vis-à-vis* blending requirements of diesel adopted by many countries (Rajgopal and Zilberman, 2007). European Union and India have set targets of 10 and 20% replacement of transport fossil fuel with biodiesel by 2020 and 2012, respectively. (Biswas *et al.,* 2010; Rosch and Skarka, 2009). In recent years, *Jatropha curcas* L., a perennial plant belonging to the family *Euphorbiaceae* has received considerable interest of the researchers as a potential source of non-edible vegetable oil. Its multifarious benefits as a source of green manure, soil ameliorator and improve rural economy by generating huge manpower employment during various stages of its cultivation and downstream processing makes it a potential candidate for large-scale plantation on marginal lands (Abdelgadir *et al.,* 2007; Behera *et al.,* 2010; Kheira and Atta, 2009; Kochhar *et al.,* 2008; Mishra, 2009; Rao *et al.,* 2008; Sunil *et al*., 2008). However, the current seed biomass output of *Jatropha* for production of biofuels is inadequate to completely replace fossil fuels (Ruth, 2008). Despite growing advocacy for *Jatropha* for large-scale cultivation, its systematic yield improvement studies, especially the nutritional requirements of the crop in marginal lands of tropical agro climatic conditions have not been adequately addressed. Although plant growth and yield is considerably influenced by application of inorganic fertilizers, striking a balance between increased yield attributes and use of optimum level of N:P:K is critical for *Jatropha* to evolve as a commercial crop. Therefore the present study was undertaken to evaluate the effect of various combinations of N:P:K fertilizers on growth, development, seed yield and oil content of *Jatropha* under the tropical agro climatic conditions of eastern India.

Materials and methods

The experiment was conducted on a five year old *Jatropha* plantation cv. 'Baramunda' at IMMT research farm, Bhubaneswar (20°40' North and 85°50' East) during 2008 and 2009. The mean temperature, rainfall, humidity and evaporation during the cropping period are presented in Fig. 1. The soil of IMMT is classified as Aeric Tropaquept with soil order Inceptisol and composed of sandy loam (83.2%), sand (6.6%), silt and clay (10.2%) with pH 5.52 and EC 0.076 mS cm^{-1}. The fertilizer experiments were conducted in randomized block designs with three replications for each of the treatments. The plot size was 196 m^2 and number of plants/plot was twenty-five. Fertilizer applications were initiated at the commencement of new growth phase when the plants put forth new leaves dur-

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ing February-March, after senescence. Each plant received N:P:K fertilization, either singly or in combination, in the form of urea (N), single super phosphate (P) and muriate of potash (K). The two levels of fertilizer doses used in the experiments were N (60 and 40 g/plant), P (80 and 100 g/plant) and K (75 and 60 g/plant). Altogether there were 15 treatments of fertilizer doses, applied either alone or in combination. Nitrogen was applied in two equal split doses *i.e.,* 1st half at the initiation of the experiment with full dose of P and K and the 2nd half after one month of 1st application.

Biometrical observations from five randomly selected plants were recorded, leaving the border ones. The plant height, collar diameter (in cm) and number of branches were measured on each of the selected plants in three replications at the end of final fruiting. Under irrigated condition *Jatropha* exhibited two flushes of flowering. The 1st flush started in March whose fruiting overlapped with 2nd flush during May. Therefore the phenological parameters like number inflorescence/plant, number of flowers/inflorescence, number of female flowers/inflorescence, male to female flower ratio, number of fruits per bunch as well as per plant were recorded separately for each flush of flowering period.

The seed yield was the sum of 1st and 2nd phase of flowering. The seeds were manually dehusked from the harvested fruits, dried, winnowed and kept in muslin cloth bags. Seed length and breadth were measured with the help of a slide caliper. For single seed and 100 seed weight (test weight), bold and healthy seeds were selected from each lot/replication, weighed and expressed in grams.

The seed oil was extracted through solvent extraction method with the help of Soxhlet apparatus. Petroleum ether (boiling point 40°C-60°C) was used as solvent. Healthy seeds weighing 100 grams from respective treatments were grinded and placed in the apparatus. After a couple of hours the extracts were taken out and fitted to rotary evaporator for solvent evaporation and recovery.

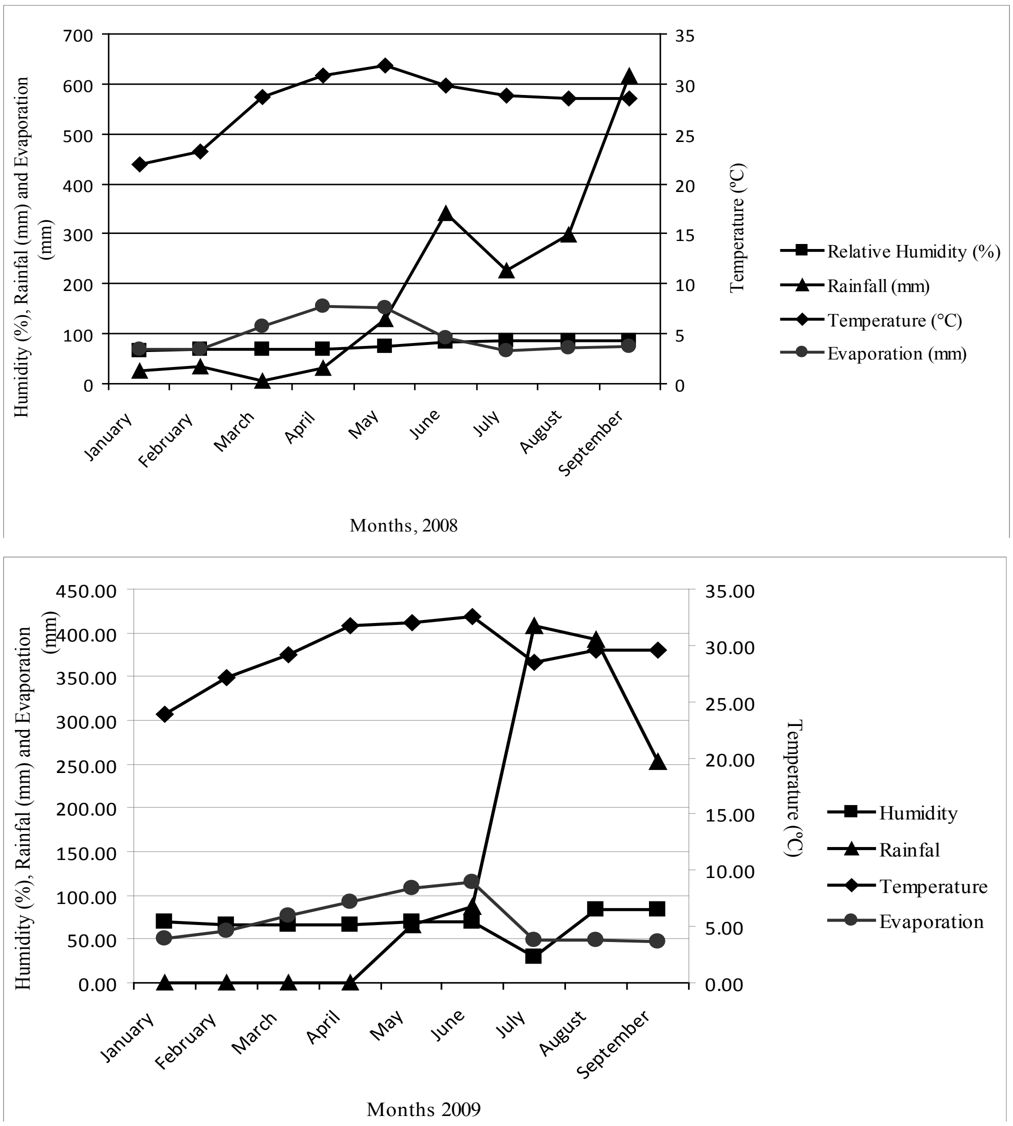

Fig. 1. Meteorological data of cropping years (Source: Department of Agricultural Meteorology, O.U.A.T., Bhubaneswar)

The oil thus obtained was weighed and expressed in % (w/w). Data pertaining to the above parameters were subjected to statistical analysis. Analysis of variance was carried out following the procedure of Panse and Sukhatme (1976).

Results and discussion

Growth characteristics

The application of nitrogen at higher level (N_{60}) significantly increased the plant height, number of branches and girth, while combined fertilizer treatment with $P_{100}K_{60}$ exhibited maximum collar girth over other treatments (Tab. 1). Nitrogen is a major nutritional element required for tissue differentiation and its role in increasing plant growth and development are well documented by various workers (Aziz, 2007; Shedeed *et al.,* 1986). Like nitrogen phosphorous is an essential constituent of the genetic material and augments cell division (Aziz, 2007). The increased collar girth, as observed in the present study in respect to phosphorous treatment might be due to increased rate of new cell formation.

Tab. 1 Effect of N, P and K on growth characteristics of *Jatropha curcas* (Pooled)

Treatments	Plant height	Collar girth	No. of branches
N_{60}	237.57	28.34	37.62
P_{80}	224.53	21.19	28.47
K_{75}	230.12	25.91	30.53
$N_{60}P_{80}$	231.94	26.85	37.52
$N_{60}K_{75}$	220.94	25.44	35.88
$P_{80}K_{75}$	203.29	24.58	36.45
$N_{60}P_{80}K_{75}$	221.60	24.43	36.40
N_{50}	209.52	23.82	32.35
P_{100}	221.65	23.08	36.81
K_{60}	226.43	25.40	35.52
$N_{50}P_{100}$	217.61	27.60	33.98
$N_{50}K_{60}$	196.25	26.80	30.31
$P_{100}K_{60}$	197.20	29.12	28.71
$N_{50}P_{100}K_{60}$	215.04	23.83	31.64
Control	186.26	20.51	25.84
CD 5%	5.28	0.41	2.60

Flowering and fruiting characteristics

The pooled analysis of the results indicated that the flowering phenomenon in *Jatropha* was earlier in N_{60} and $N_{60}P_{80}$ treatments during the 1st and 2nd phase of flowering respectively, as compared to other treatments (Tab. 2 and Tab. 3). The results are in agreement with previous report in *Jatropha* where nitrogen at higher level hastened the flowering process (Yong *et al.*, 2010). Leleu *et al.* (2000) reported early flowering phenomenon in nitrogen supplemented rapeseed plants, while nitrogen deficiency study in lupin resulted in delayed flowering (Ma *et al.,* 1997). The yield of fruits depends upon the number of female flowers and an increase in the number of female flowers implied higher fruit yield. Results of the present study revealed that during 1st phase of flowering plants undergoing $N_{50}K_{60}$ treatment showed higher number of female flowers but with low yield of fruits (Tab. 2). On the other hand, during the 2nd phase of flowering N_{60} treatment resulted in increased number of female flowers with a concomitant

Tab. 2. Effect of N, P and K on 1st phase flowering and fruiting of *Jatropha* (Pooled)

Treatments	1st phase flowering and fruiting							
	Flr	In	NFI	FFI	Fr	MF/FF	Fr/B	Fr/PL
N_{60}	20.67	42.82	97.78	5.87	34.05	15.94	5.17	43.57
P_{80}	21.67	31.08	124.13	5.96	42.54	19.93	4.83	65.63
K_{75}	21.67	45.46	110.07	5.11	33.86	21.48	4.00	62.15
$N_{60}P_{80}$	21.00	39.94	110.90	4.87	32.61	26.49	4.50	55.55
$N_{60}K_{75}$	22.33	22.79	137.35	4.98	28.08	27.12	4.33	44.73
$P_{80}K_{75}$	22.17	31.19	132.24	4.77	27.20	27.02	5.00	49.21
$N_{60}P_{80}K_{75}$	22.67	24.09	163.41	7.14	23.61	21.90	6.25	49.50
N_{50}	20.67	20.08	156.78	10.20	22.23	14.44	8.67	27.04
P_{100}	22.00	23.54	128.13	5.86	19.32	20.90	6.50	32.79
K_{60}	20.67	33.92	157.12	6.95	19.67	21.62	6.17	34.81
$N_{50}P_{100}$	22.33	42.35	181.73	7.62	16.27	22.90	6.50	48.04
$N_{50}K_{60}$	20.83	33.18	168.04	11.04	20.96	14.32	9.67	29.27
$P_{100}K_{60}$	21.33	24.92	140.07	9.09	21.87	14.44	8.50	32.01
$N_{50}P_{100}K_{60}$	22.67	19.11	173.86	8.27	21.22	20.09	6.83	34.11
Control	21.50	15.77	161.79	7.31	20.57	21.17	6.50	46.19
CD 5%	1.64	2.21	2.97	0.47	2.39	1.68	1.06	3.62

Tab. 3. Effect of N, P & K on 2nd phase flowering and fruiting of *Jatropha* (Pooled)

Treatments	2nd phase flowering and fruiting							
	Flr	In	NFI	FFI	Fr	MF/FF	Fr/B	Fr/PL
N_{60}	65.77	44.23	168.51	19.13	26.37	5.25	13.04	270.28
P_{80}	65.05	32.61	131.21	13.36	27.50	8.88	11.35	111.12
K_{75}	66.32	36.85	114.00	11.64	28.67	8.83	11.49	87.34
$N_{60}P_{80}$	64.91	41.31	108.80	17.25	24.50	5.32	9.80	217.43
$N_{60}K_{75}$	68.27	27.59	136.59	12.26	25.33	10.25	9.70	205.00
$P_{80}K_{75}$	72.70	32.79	133.25	11.71	23.00	10.39	10.04	119.83
$N_{60}P_{80}K_{75}$	71.14	26.63	160.81	13.52	25.83	10.95	12.13	116.40
N_{50}	69.92	24.02	156.45	9.44	26.33	15.60	7.72	69.78
P_{100}	66.97	40.57	130.61	10.92	27.83	11.00	8.17	109.97
K_{60}	65.59	35.52	157.94	11.93	25.83	12.26	10.38	134.75
$N_{50}P_{100}$	70.62	43.55	184.59	16.76	25.50	10.05	11.41	207.92
$N_{50}K_{60}$	70.83	31.97	100.17	16.02	26.83	7.81	13.10	167.19
$P_{100}K_{60}$	66.06	26.53	139.23	11.64	23.50	11.02	9.59	267.38
$N_{50}P_{100}K_{60}$	64.96	23.11	172.17	16.25	24.83	9.67	11.69	221.81
Control	69.70	17.53	163.78	9.42	26.17	16.52	6.56	154.91
CD 5%	2.11	2.50	3.32	1.02	1.94	0.92	0.77	6.39

Tab. 4. Effect of N, P and K on seed and oil characters of *Jatropha* (Pooled)

Treatments	Seed characters					
	SY	SL	SB	S wt	Test Wt.	OIL%
N_{60}	427.21	1.86	1.15	0.41	34.83	35.05
P_{80}	219.95	1.83	1.25	0.37	36.85	33.83
K_{75}	155.08	1.86	1.14	0.31	34.63	34.44
$N_{60}P_{80}$	244.56	1.81	1.14	0.27	29.47	34.04
$N_{60}K_{75}$	244.56	1.88	1.18	0.29	35.22	34.11
$P_{80}K_{75}$	183.08	1.76	1.20	0.33	28.03	34.59
$N_{60}P_{80}K_{75}$	200.87	1.82	1.20	0.35	37.48	33.01
N_{50}	233.37	1.81	1.19	0.25	32.03	33.47
P_{100}	164.92	1.64	1.10	0.35	33.84	32.11
K_{60}	207.22	1.72	1.23	0.37	32.23	33.43
$N_{50}P_{100}$	301.29	1.85	1.20	0.35	32.79	34.33
$N_{50}K_{60}$	226.92	1.76	1.11	0.35	30.50	34.43
$P_{100}K_{60}$	384.93	1.86	1.20	0.39	30.03	32.38
$N_{50}P_{100}K_{60}$	222.79	1.83	1.15	0.26	27.86	35.69
Control	80.08	1.84	1.20	0.35	30.04	32.00
CD 5%	10.04	0.01	0.01	0.01	4.87	0.84

Tab. 5. Analysis of variance for growth, phenological and seed characters of *Jatropha curcas* as influenced by N, P and K (Pooled)

Parameters		Replication (2)	Treatment (14)	Error (28)
Ht.		0.75	1295.41**	20.00
Gr.		0.19	36.05**	0.12
Br.		11.77	85.93**	4.88
Flr.	1st	1.07	3.20	1.93
In.	P	96.18	538.67**	3.50
NFI	h	53.18	3913.63**	6.35
FFI	a	0.18	23.08**	0.16
Fr	s	5.97	317.64**	4.11
MF/FF	e	0.54	113.75**	2.06
Fr/ B		1.31	0.01	0.81
Fr/ Pl		18.09	842.01**	9.42
Flr.	2nd	2.15	42.55**	3.20
In.	P	38.91	389.39**	4.46
NFI	h	23.81	3711.46**	7.90
FFI	a	0.52	53.23**	0.76
Fr	s	2.05	14.16**	2.71
MF/FF	e	0.65	57.10**	0.61
Fr/ B		0.52	21.39**	0.44
Fr/ Pl		111.00	24686.50**	2.92
SY	1st +2 nd	154.25	47314.19**	72.24
SL	P	0.0007	0.02*	0.0001
SB	h	0.001	0.01*	9464.1
SW	a	0.001	0.01*	0.0002
TW	s	12.35	55.72**	17.06
OIL	e	0.48	6.84**	0.50

* Significant at 5 %, ** Significant at 1 %

higher yield of fruits (Tab. 3). The low yield of fruits in the 1st phase may be attributed to inadequate availability of moisture to the plants during the summer months, which was not the case during 2nd phase of flowering when the monsoon rains had commenced. In the present study the yield of *Jartopha* fruits increased significantly due to nitrogen treatment; maximum value being 270.28 fruits/ plant recorded in treatment N_{60} in the 2nd flush. Thus the present set of results conclusively demonstrated the overall beneficial effect of application of nitrogen (Tab. 2 and Tab. 3).

Seed and oil characteristics

In general, *Jatropha* crop undergoing various doses of fertilizer treatments exhibited increased yield of seeds in comparison to the control; the maximum increase being recorded in plants undergoing N_{60} treatment where the seed yield was about 433% over untreated plants (Tab. 4). Application of P in combination with K fertilizer ($P_{100}K_{60}$) was also found to be effective in significantly enhancing the yield of seeds, although such a similar trend was not observed in the recorded data pertaining to seed test weight. Reddy *et al.* (1990) reported that application of higher doses of nitrogen resulted in higher seed yield in oil bearing crop, soybean. N and K in higher doses, when applied alone marginally increased the seed length, while the combined application of $N_{60}K_{75}$ resulted in significant synergistic effect over other treatments. Nitrogen in higher dose (N_{60}) was also effective in resulting higher seed weight, while a combined application of $N_{60}P_{80}K_{75}$ fertilizers resulted in significantly higher test weight of seeds. The seed weight has a direct bearing on the final economic yield of a crop. The differences in the seed weight are generally related to the period between anthesis and maturation of seeds. During this period supply of assimilates to the fruits and formative seeds is crucial and plants with better supply of balanced nutrients are at greater advantage than those under the low nutrient supply (Scott *et al.,* 1973).

The fixed seed oil content of the *Jatropha* determined in the present study was within the same range reported for this crop by previous workers from other eco-climatic regions of India (Kochhar *et al.,* 2008; Sunil *et al.,* 2008). Combined application of $N_{50}P_{100}K_{60}$ exhibited significantly higher oil content (35.69%); whereas plants treated with N_{60} singly, closely followed the trend (35.05%). In the present study plants receiving N fertilizer were vigorous and produced overall healthy seeds as compared to others and also increased in the oil content. These observations are in accordance with Ashraf *et al.* (2006) who reported black cumin plants receiving N fertilizer with higher growth rate and yield of seeds and seed oil. On the other hand, Yong *et al.* (2010) found no significant difference in the oil content of *Jatropha* seeds with the increase in nitrogen levels. In several studies, it was found that seed oil content responded weakly to increased nitrogen supply due to the concomitant increase in heavier protein production under high N nutrition (Abbadi *et al.,* 2008). This could lead to retarded synthesis of fatty acids. Such differences in the oil contents were also noticed in the present study. On the other hand, application of higher nitrogen level although marginally increased the seed oil content, the total yield of seeds/plant was significantly higher than other fertilizer treated plants (Tab. 4). In a broader sense, from yield point of view it is not only the seed oil content but also the total seed yield which needs to be taken into account, when the techno-economics of *Jatropha* cultivation in unit area is evaluated. Therefore *Jatropha* plants with comparatively low oil content but with higher seed output can match still other elite plants with higher oil content.

The present study clearly demonstrates the nutritional importance of N supply to *Jatropha* crop for better economic returns and the results reveal application of N 60 g/plant to be beneficial for enhanced yield of a five-year old standing crop under tropical agroclimatic condition in an Aeric Tropaquept soil type. The optimum level of fertilizer requirement for a perennial crop like *Jatropha* is dynamic and changes with the age of plantation. Therefore the fertilizer requirement studies need further long-tem evaluation for different agro-ecological regions.

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Appendix

Legends	Characters
Ht.	Plant height (cm)
Gr.	Collar girth (cm)
Br.	Number of branches
Flr.	Day to flowering
In.	Number of inflorescence
NFI	Number of flowers/ inflorescence
FFI	Number of female flowers/ inflorescence
Fr	Days to fruiting
MF/FF	Male to female flower ratio
Fr/ B	Number of fruits/ bunch
Fr/ Pl	Number of fruits/ plant
SY	Seed yield (kg/ ha.)
SL	Seed length (cm)
SB	Seed breadth (cm)
SW	Single seed weight (g)
TW	Test weight (g)
OIL	Oil content (%)

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