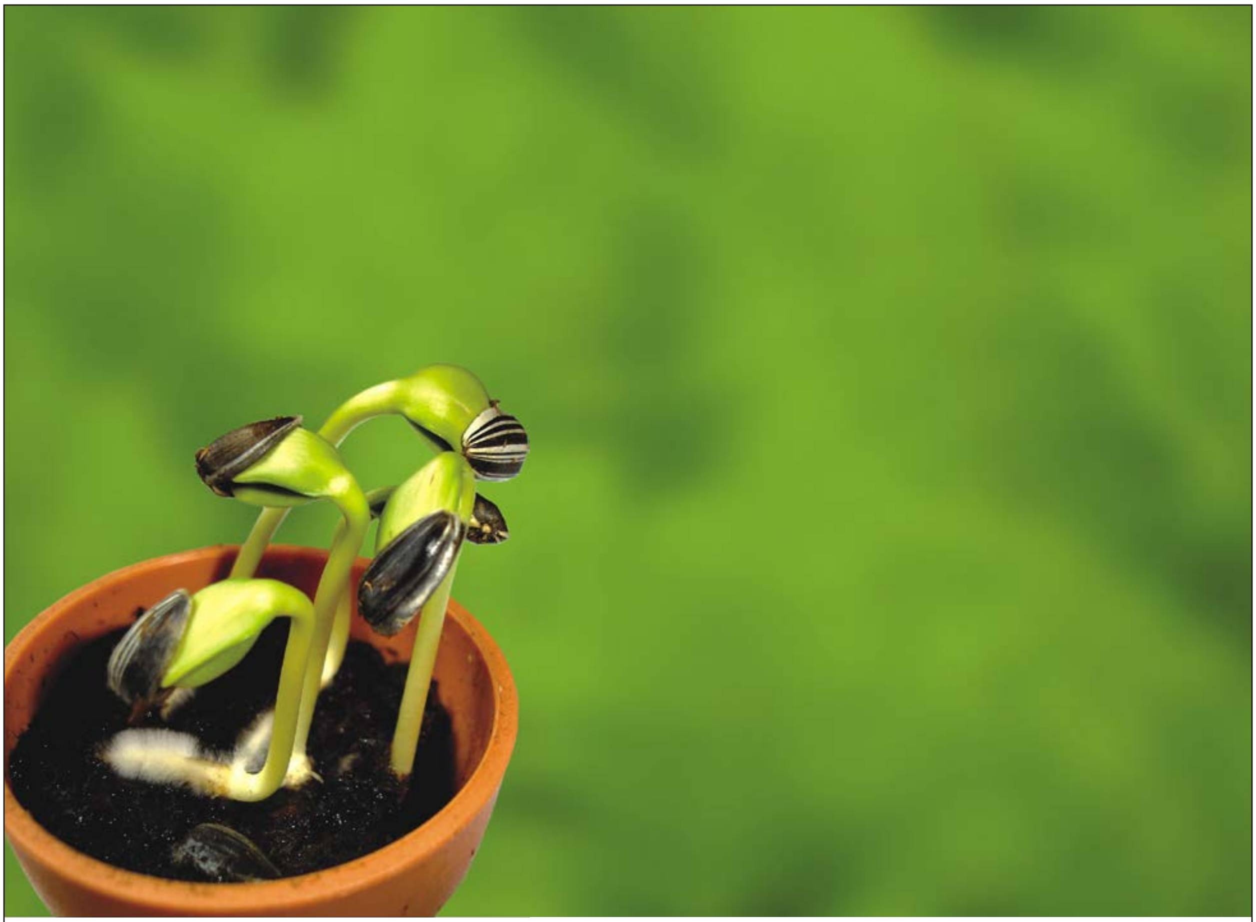

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Research Article

Variability in Physiological and Yield Performance of Castor (*Ricinus communis* L.) Genotypes under Rainfed Condition of Alfisols

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Abstract

A field study was carried out with twelve Central Research Institute for Dryland Agriculture (CRIDA) castor genotypes along with the check 48-1 to assess the variability in physiological parameters like photosynthetic rate (Pn), stomatal conductance (gs), transpiration rate (Tr) and Water Use Efficency (WUE) along with seed yield during kharif, 2013. The results revealed that two CRIDA genotypes viz., CRC-2 and CRC-9 were found to be superior over the check for seed yield and have lower gs and Tr thereby recorded improved WUE. The Pn values of selected castor genotypes were not varied significantly and the WUE is mainly influenced by Tr. Among the physiological parameters, gs and Tr showed significant negative correlation with seed yield revealing that the gs and Tr values need to be low to improve the seed yield of castor under rainfed condition.

Key words: Seed yield, photosynthetic rate, WUE, genotypes, transpiration rate

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Castor (*Ricinus communis* L.) belongs to Euphorbiaceace family which is found in both tropical and sub-tropical regions of the world (Weiss, 2000). Castor is indigenous to the southeastern Mediterranean Basin, Eastern Africa and India but is widespread throughout tropical regions. Castor seed is the source of castor oil, which has a wide variety of uses. Castor oil is one of the important raw materials for the chemical and polymer industries (Mutlu and Meier, 2010) are used as biodiesel stock (Hall *et al*., 2009; Da Silva Cesar and Batalha, 2010). With its unlimited applications, castor oil has a tremendous worldwide demand and it accounts for 0.15% of vegetable oils (Scholz and da Silva, 2008). India and Brazil together accounts for more than 80% of the castor oil supply. In India, castor is cultivated in an area of 8.4 lakh ha under both irrigated and rainfed conditions. Castor has the potential for its use in bioenergy and industrial feed stock due to its high oil content and has the adaptability to grow under drought and saline conditions (Severino *et al*., 2012). India is the first country in the world to exploit hybrid vigour of castor crop on commercial scale (Ramchandram and Rao, 2012).

Castor is considered to be a drought hardy crop and grows well under dry and warm regions receiving a rainfall of 500-750 mm. It has a wide range of adaptation and has the ability to grow on marginal sites subjected to drought and saline conditions. To produce higher yields, it requires a moderate temperature of 20-26°C and low humidity (Gangaiah, 2008). High temperature above 41°C at flowering time even for a short period results in blasting of flowers and poor seed set. The kharif season crop essentially grown as rainfed crop, require a minimum of 500-700 mm rainfall depending on the soil type and higher yield can be obtained with 1-2 supplemental irrigations (Sharma *et al*., 2010).

In India, Telangana and Gujarat are well known for castor production and productivity. To develop high yielding castor genotypes that get fit into the present cropping system, it is important to create the genetic variability for the selection of desirable variant (Sarwar and Chaudhry, 2008). However, as major cropped area is under rainfed, the physiological efficiency of the genotypes especially water use efficiency has become pivotal. Under limited water supply, it maintains efficient stomatal control with a high level of net CO_2 fixation (Severino *et al*., 2012). In order to identify the variability in the physiological parameters which are indicative of moisture stress tolerance and towards this endeavour 12 varieties of castor from CRIDA were evaluated at field conditions along with the popular check to find out the best lines with better physiological efficiency coupled with higher seed yield. This identification of better lines would be helpful in the process of improving castor productivity and production.

MATERIALS AND METHODS

A field study was conducted during kharif with twelve CRIDA castor genotypes, viz., CRC-1, CRC-2, CRC-3, CRC-4, CRC-5, CRC-6, CRC-7, CRC-8, CRC-9, CRC-10, CRC-11, CRC-12 and a check 48-1 at Hayathnagar research farm, Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad. The trial was sown on June 23rd, 2013 in RBD with three replications and the crop was raised purely under rainfed conditions. The crop received 904.5 mm rainfall spreading in 60 rainy days during the crop growth period and the crop experienced 3 dry spells (<2.5 mm) of 10 days or more with the first dry spell during the vegetative stage, the second dry spell of 27 days during the maturation of secondary raceme and a no rainfall of 91 days during initiation to maturation of tertiary racemes. During the crop growth period, the average temperature was 23.4°C with minimum and maximum of 8.4 and 38.6°C, respectively. Each genotype was sown in 5 m length of three rows with plant to plant spacing of 30 cm and 1 m between rows. At 50% flowering of primaries (53 DAS), the physiological observations such as photosynthesis (Pn), stomatal conductance (gs), transpiration rate (Tr) were recorded with portable photosynthesis system (LICOR-6400, USA) and WUE was calculated as the ratio Pn to Tr. The capsules of first (primaries), second (secondaries) and third (tertiaries) order spikes were pooled and the seed yield and yield components were recorded on per plant basis.

RESULTS AND DISCUSSION

Seed yield: The seed yield of all the 13 genotypes ranged from 32 g per plant (CRC-7) to 73.6 g per plant (CRC-2) with an average of 46.8 g per plant. Among the 12 CRIDA genotypes, CRC-2 (73.6 g per plant) CRC-11 (57.6 g per plant) and CRC-9 (55.3 g/plant) were superior over the check, 48-1 (53.2 g/plant). Ahmed *et al*. (2012) reported higher seed yield in two castor mutants CBM-7 and CBM-17 over the check DS-30.

The seed yield from three spike orders varied in different selected castor genotypes. In majority of the genotypes the contribution of third order spike was higher than other two orders. However, in genotypes CRC-5 and 48-1 all the three spike orders contributed equally to final seed yield. The seed yield of primaries ranged from 7.5 (CRC-12) to 17.0 g per plant (CRC-2), for secondaries it ranged from 6.6 g per plant (CRC-4) to 21.9 g per plant (CRC-11) and for tertiaries the range was from 11.1 g per plant (CRC-5) to 39.3 g per plant (CRC-2). The

Table 1: Physiological parameters and seed yield in castor genotypes during kharif, 2013

Genotype	Pn (µmol CO_2 m^{-2} sec^{-1})	gs (cm sec^{-1})	Tr (mmol H_2O m^{-2} sec^{-1})	WUE (µmol CO_2 $mmol^{-1}$ H_2O m^{-2} sec^{-1})	Seed yield (g $plant^{-1}$)
CRC-1	34.5	0.854	11.3	3.12	34.5
CRC-2	73.6	0.471	6.7	4.65	73.6
CRC-3	41.7	0.826	11.5	3.07	41.7
CRC-4	47.7	1.072	13.5	2.29	47.7
CRC-5	39.2	1.073	13.1	2.61	39.2
CRC-6	41.5	0.582	8.1	4.92	41.5
CRC-7	32.0	1.024	12.9	2.45	32.0
CRC-8	50.6	0.611	8.3	4.49	50.6
CRC-9	55.3	0.481	7.4	4.37	55.3
CRC-10	40.3	0.617	8.2	3.95	40.3
CRC-11	57.6	0.867	11.8	3.05	57.6
CRC-12	40.9	0.606	8.8	4.06	40.9
48-1	53.2	0.764	10.0	3.15	53.2

Pn: Photosynthesis rate, gs: Stomatal conductance, WUE: Water use efficiency, Tr: Transpiration rate

Table 2: ANOVA for physiological parameters in castor genotypes during kharif, 2013

Source	DF	Pn	gs	Tr	WUE
Mean sum of squares					
Replication	4	14.254	0.036	3.097	0.204
Genotype	12	25.213	0.229**	27.777**	3.977**
Error	48	16.190	0.034	2.967	0.728
CV (%)		12.040	24.280	16.93%	24.00%

*p<0.05 level, **p<0.01, Pn: Photosynthesis rate, gs: Stomatal conductance, WUE: Water use efficiency, Tr: Transpiration rate, DF: Degree of freedom

impact of first, second and third orders of castor crop vary the final seed yield due to the genotype, environmental (Fanan *et al*., 2009; Neto *et al*., 2009; Zuchi *et al*., 2010a, b; Vallejos *et al*., 2011) and location factors (Abimiku *et al*., 2012). In the present trial, the crop was affected by the infection of Botrytis during maturity of primaries and this also influenced the yield of secondaries of susceptible genotypes. From the overall seed yield of three spike orders it was observed that three CRIDA genotypes CRC-2, CRC-11 and CRC-9 superior over the check 48-1. The genotype CRC-2 was also found to be resistant to Botrytis disease as check 48-1.

Physiological parameters: The ANOVA of physiological characteristics of castor genotypes were presented in Table 1 and highly significant ($p \leq 0.01$) variation for the physiological parameters gs, Tr and WUE was observed (Table 2) whereas photosynthetic rate was non-significant.

Photosynthetic rate (Pn-µmol CO_2 m^{-2} sec^{-1}): The Pn values of selected castor genotypes was not varying significantly and it ranged from 30.72 (CRC-2) to 37 µmol CO_2 m^{-2} sec^{-1} (CRC-6) and check 48-1 with 30.80 µmol CO_2 m^{-2} sec^{-1}. The high yielding genotypes CRC-2 30.72 and CRC-9 (31.94 µmol CO_2 m^{-2} sec^{-1}) recorded lower Pn values whereas CRC-11 (35.80 µmol CO_2 m^{-2} sec^{-1}) was with moderate values. Dai *et al*. (1992) reported that decrease in photosynthesis and increase in photorespiration under high VPD can be accounted for closure of stomata and Bindumadhava *et al*. (2005) opined that stable isotope ratios of $^{13}C/^{18}O$ provide a powerful option in identifying the desirable genotypes with superior photosynthetic capacity which can be used in crop improvement.

Stomatal conductance (gs cm sec^{-1}): The gs of the 13 selected castor genotypes recorded a significant difference and it ranged from 0.471 (CRC-2) to 1.073 cm sec^{-1} (CRC-5). The two high yielding CRIDA genotypes, CRC-2 (0.471) and CRC-9 (0.481 cm sec^{-1}) recorded the lower values than the check 48-1 (0.764 cm sec^{-1}) for gs. Earlier reports of Sausen and Rosa (2010) showed that castor bean plants combine an efficient stomatal control with high levels of net CO_2 fixation.

Transpiration rate (mmol H_2O m^{-2} sec^{-1}): The transpiration rate of the genotypes ranged from 6.73 (CRC-2) to 13.58 mmol H_2O m^{-2} sec^{-1} (CRC-4) with a significant difference among the genotypes. The Tr values of the high yielding CRIDA genotypes CRC-2 (6.73) and CRC-9 (7.49 mmol H_2O m^{-2} sec^{-1}) were lower than the check 48-1 (10 mmol H_2O m^{-2} sec^{-1}). Earlier reports by Sheshshayee *et al*. (2005) revealed that transpiration rate can increase either because of increased stomatal conductance or when the vapour pressure difference between the leaf and air is increased. The reports of Sausen and Rosa (2010) revealed that the water loss by transpiration was minimized by an early closure of stomata in castor.

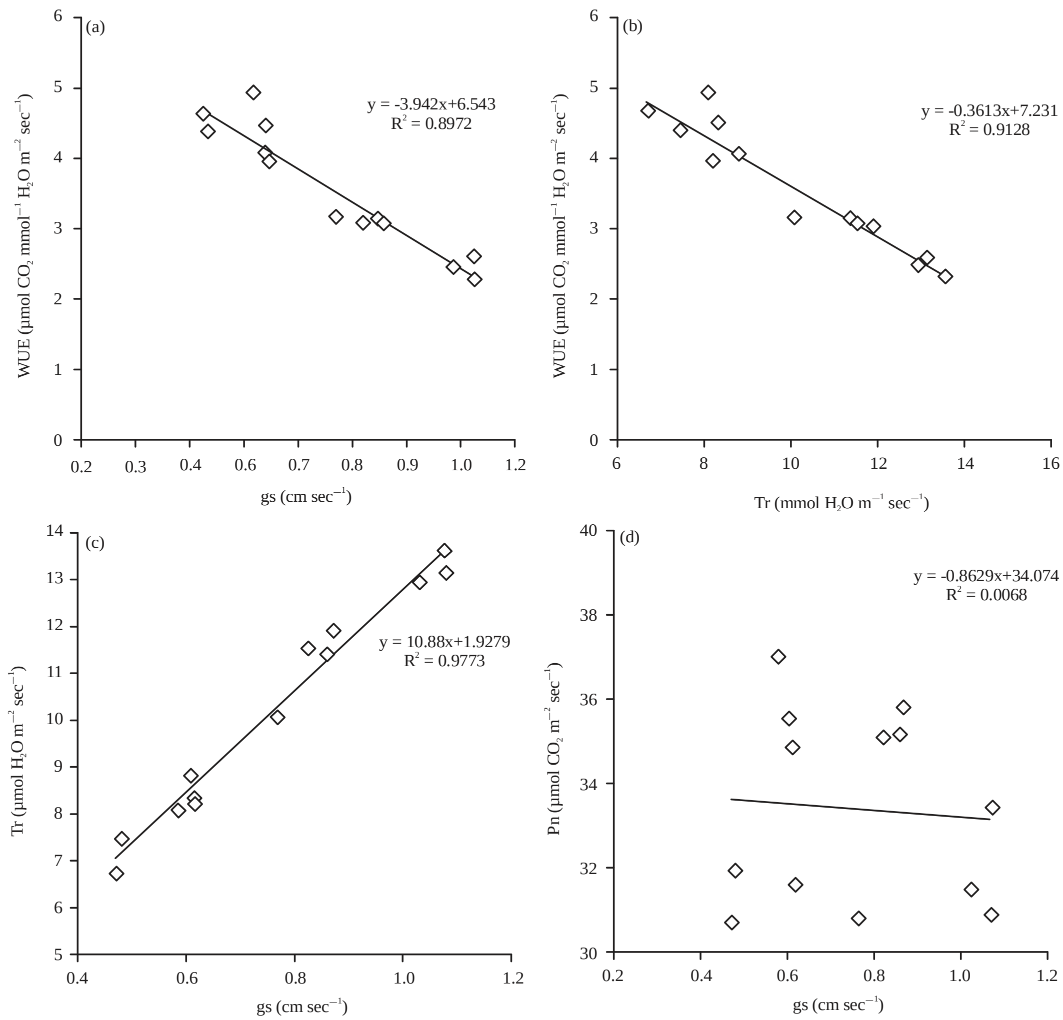

Fig. 1(a-d): Relationships between the selected physiological parameters of castor genotypes (a) gs and WUE, (b) Tr and WUE, (c) gs and Tr and (d) gs and Pn selected physiological parameters of castor genotypes

Table 3: Correlation of physiological parameters with the seed yield in castor genotypes

Parameters	Pn	gs	Tr	WUE	Seed yield
Pn	1.0000				
Gs	-0.0822	1.000			
Tr	-0.0170	0.988**	1.000		
WUE	0.2480	-0.947**	-0.955**	1.000	
Seed yield	-0.3110	-0.500*	-0.492*	0.413	1.000

*p<0.05, **p<0.01, Pn: Photosynthesis rate, gs: Stomatal conductance, WUE: Water use efficiency, Tr: Transpiration rate

Water Use Efficiency (WUE) (µmol CO_2 mmol^{-1} H_2O m^{-2} sec^{-1}): The WUE of the genotypes was calculated as the ratio of Pn and Tr and it ranged from 2.29 (CRC-4) to 4.92 µmol CO_2 mmol^{-1} H_2O m^{-2} sec^{-1} (CRC-6) and better yielding genotypes CRC-2 and CRC-9 recorded higher WUE over check 48-1. Lakshmamma *et al.* (2010) observed WUE was strongly correlated with the root traits. Through enhanced WUE, significant improvement in productivity was demonstrated in crops like groundnut by Condon *et al.* (2004).

The regression equation between gs has significant positive relation with Tr (r^2 = 0.9773) whereas WUE has significant negative relation with gs (r^2 = 0.8972) and Tr (r^2 = 0.9128) revealing that the WUE of castor is mainly dictated by Tr and which in turn by gs and not Pn (Fig. 1). The correlation studies (Table 3) also revealed that gs was significantly and positively correlated with Tr (0.988**) and significantly and negatively correlated with WUE (-0.947**) and seed yield (-0.500*). Significant negative correlation was observed for Tr with WUE (-0.955**) and seed yield (-0.492*). Hence for identifying or developing genotype for better water use and higher seed yield, lower gs and Tr need to be considered. The WUE is strongly correlated in C_3 plants with stomatal conductance (Medrano *et al*., 2002). Jatoi *et al*. (2012) experiments with wheat showed that there was a negative correlation of gs with yield and its traits. Bindumadhava *et al*. (1999) opined that ^{18}O acts as surrogate for transpiration efficiency and gs and high ^{18}O shows high transpiration rate which is related to yield directly. Seed yield and its traits of castor are useful to bring the crop improvement (Udayabhanu *et al*., 2013; Najan *et al*., 2010; Patel *et al*., 2010).

CONCLUSION

Based on the physiological and yield performance of selected castor genotypes, it can be concluded that there was significant variability in these parameters. Among the physiological parameters, gs and Tr are found to be significantly negatively correlated with seed yield. Two CRIDA genotypes CRC-2 and CRC-9 recorded lower gs and Tr with higher WUE and seed yield than check 48-1. It can be summarized that for rainfed condition, the castor genotypes need to have not only high seed yield but also low gs and Tr for high WUE values.

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REFERENCES

Abimiku, O.E., E.D. Azagaku and E. Ndor, 2012. Genetic variability and correlation studies in some quantitative characters in castor (*Ricinus cummunis* L.) accessions. Asian J. Agric. Sci., 4: 368-372.

Ahmed, H.M., G. Sarwar and M. Ahsan ul Haq, 2012. Genetic variability and interdependence of morphological traits in castorbean (*Ricinus communis* L) mutants. Songklanakarin J. Sci. Technol., 34: 279-286.

Bindumadhava, H., M.S. Sheshshayee, R. Devendra, T.G. Prasad and M. Udayakumar, 1999. Oxygen (^{18}O) isotopic enrichment in the leaves as a potential surrogate for transpiration and stomatal conductance. Curr. Sci., 76: 1427-1428.

Bindumadhava, H., M.S. Sheshshayee, G. Shashidhar, T.G. Prasad and M. Udayakumar, 2005. Ratio of stable carbon and oxygen isotope discrimination ($^{13}C/^{18}O$) reflects variability in leaf intrinsic carboxylation efficiency in plants. Curr. Sci., 89: 1256-1258.

Condon, A.G., R.A. Richards, G.J. Rebetzke and G.D. Farquhar, 2004. Breeding for high water-use efficiency. J. Exp. Bot., 55: 2447-2460.

Da Silva Cesar, A. and M.O. Batalha, 2010. Biodiesel production from castor oil in Brazil: A difficult reality. Energy Policy, 38: 4031-4039.

Dai, Z., G.E. Edwards and M.S. Ku, 1992. Control of photosynthesis and stomatal conductance in *Ricinus communis* L. (castor bean) by leaf to air vapor pressure deficit. Plant Physiol., 99: 1426-1434.

Fanan, S., P.F. Medina, M.B.P. de Camargo and R. Galbieri, 2009. Description of agronomic characteristics and harvest time evaluation in the yield of castor bean cultivar IAC 2028. Bragantia, 68: 415-422.

Gangaiah, B., 2008. Agronomy-Kharif crops. http://nsdl. niscair. res.in/jspui/handle/123456789/523/browse?type= author&order=ASC&rpp=20&value=Gangaiah%2C+B.

Hall, J., S. Matos, L. Severino and N. Beltrao, 2009. Brazilian biofuels and social exclusion: Established and concentrated ethanol versus emerging and dispersed biodiesel. J. Cleaner Prod., 17: S77-S85.

Jatoi, W.A., M.J. Baloch, M.B. Kumbhar and M.I. Keerio, 2012. Heritability and correlation studies of morpho-physiological traits for drought tolerance in spring wheat. Pak. J. Agric. Agric. Eng. Vet. Sci., 28: 100-114.

Lakshmamma, P., L. Prayaga and C. Sarada, 2010. Evaluation of castor (*Ricinus communis* L.) germplasm for Water Use Efficiency (WUE) and root characters. Indian J. Plant Genet. Resour., 23: 276-279.

Medrano, H., J.M. Escalona, J. Bota, J. Gulias and J. Flexas, 2002. Regulation of photosynthesis of C_3 plants in response to progressive drought: Stomatal conductance as a reference parameter. Ann. Bot., 89: 895-905.

Mutlu, H. and M.A. Meier, 2010. Castor oil as a renewable resource for the chemical industry. Eur. J. Lipid Sci. Technol., 112: 10-30.

Najan, BR., J.R. Kadam and A.D. Kadlang, 2010. Genetic variability studies in castor *Ricinus communis* L. J. Oilseeds Res., 27: 77-79.

Neto, M.A.D., F.J.A.F. Tavora, L.A. Crisostomo and B.L.M. Diniz, 2009. NPK fertilization and sowing time for castor plant. I-Production and yield components. Revista Ciencia Agronomica, 40: 578-587.

Patel, J.R., M.P. Saiyed, C.G. Patel, R.K. Bhatt and J.P. Bhatt, 2010. Genetic variability and correlation studies in castor (*Ricinus communis* L.). Int. J. Agric. Sci., 6: 129-131.

Ramchandram, M. and V.R. Rao, 2012. Seed production in castor. Directorate of oil seeds Research, Rjendrangar, Hyderabad.

Sarwar, G. and M.B. Chaudhry, 2008. Short communication. Evaluation of castor (*Ricinus communis* L.) induced mutants for possible selection in the improvement of seed yield. Spanish J. Agric. Res., 6: 629-634.

Sausen, T.L. and L.M.G. Rosa, 2010. Growth and carbon assimilation limitations in *Ricinus communis* (Euphorbiaceae) under soil water stress conditions. Acta Botanica Brasilica, 24: 648-654.

Scholz, V. and J.N. da Silva, 2008. Prospects and risks of the use of castor oil as a fuel. Biomass Bioenergy, 32: 95-100.

Severino, L.S., D.L. Auld, M. Baldanzi, M.J.D. Candido and G. Chen *et al*., 2012. A review on the challenges for increased production of castor. Agron. J., 104: 853-880.

Sharma, B.R., K.V. Rao, K.P.R. Vittal, Y.S. Ramakrishna and U. Amarasinghe, 2010. Estimating the potential of rainfed agriculture in India: Prospects for water productivity improvements. Agric. Water Manage., 97: 23-30.

Sheshshayee, M.S., H. Bindumadhava, R. Ramesh, T.G. Prasad, M.R. Lakshminarayana and M. Udayakumar, 2005. Oxygen isotope enrichment ($\Delta^{18}O$) as a measure of time-averaged transpiration rate. J. Exp. Bot., 56: 3033-3039.

Udayabhanu, K., V.S. Rao and M.S. Rao, 2013. Genetic variability in castor (*Ricinus communis* L.) for yield and its contributing traits. Int. J. Food Agric. Vet. Sci., 3: 103-108.

Vallejos, M., D. Rondanini and D.F. Wassner, 2011. Water relationships of castor bean (*Ricinus communis* L.) seeds related to final seed dry weight and physiological maturity. Eur. J. Agron., 35: 93-101.

Weiss, E.A., 2000. Oilseed Crops. 2nd Edn., Blackwell Science, Oxford, UK.

Zuchi, J., G.A.P. Bevilaqua, C.S. Sediyama and J.C. Zanuncio, 2010a. Variation on castor seed quality and size by sowing time and floral order. Revista Ciencia Agronomica, 41: 403-408.

Zuchi, J., J.C. Zanuncio, G.A.P. Bevilaqua, S.T. Peske and S.D. dos Anjos e Silva, 2010b. Castor yield components according to floral order and sowing season in the Rio Grande do Sul State. Revista Ciencia Agronomica, 41: 380-386.