Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; SP1: 68-72

Pushpanathan KR
Assistant Professor (Agronomy), TANUVAS, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

BJ Pandian
Director, WTC, TANUVAS, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

G Mariappan
Agricultural officer, TANUVAS, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

P Jeyakumar
Professor & Head- Crop Physiology, TANUVAS, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Correspondence
Pushpanathan KR
Assistant Professor (Agronomy), TANUVAS, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Effect of drip fertigation on biochemical parameter and castor equivalent yield of castor + onion inter cropping system

Pushpanathan KR, BJ Pandian, G Mariappan and P Jeyakumar

Abstract
Field experiments were conducted in farmer's field at Kokalai village, Namakkal during *rabi* 2011-12 and 2012-13 to study the effect of drip irrigation regimes and fertigation levels on biochemical characters and castor equivalent yield in castor + onion intercropping system. Experiment was laid out in split plot design with three replications. Castor + onion intercropping system showed significant influence in the biochemical parameters and castor equivalent yield of crops under drip fertigation system. Results revealed that drip irrigation at 80 per cent CPE with application of 100 per cent RDF as water soluble fertilizer (WSF) registered better biochemical characters *viz.*, total chlorophyll; chlorophyll stability index, soluble protein and castor equivalent yield than 60 per cent and 40 per cent CPE during both the years. Whereas water stress at 40 per cent CPE with 75 per cent RDF as conventional fertilizer registered more leakage of cell membrane characters and more proline accumulation, during both the years compared to other treatments.

Keywords: Castor, drip irrigation, fertilizer levels, CMI; TCC; CSI; Proline; soluble protein content and CEY

Introduction
Castor (*Ricinus communis* L.) is a fast growing C_3 plant of indeterminate type native of tropical Africa (Weiss, 1971) [23], member of Spurce family (Euphorbiaceae). Castor is a drought tolerant crop plant well adapted to low moisture conditions by deep rooting and thrive well under conserved moisture. Cell membrane is first target of many plant stresses and it is generally accepted that the maintenance of their integrity and stability under water stress conditions is a major component of drought tolerance in plants. It has been demonstrated recently that electrolyte leakage measurements may be correlated with several physiological and biochemical parameters of the plant in response to environmental conditions (Vainola and Repo, 2000) [21], membrane acyl lipid concentrations (Lauriano *et al*., 2000) [9].
The levels of biochemical components such as chlorophylls, total protein and free proline were measured during the stress as well as the recovery periods. The chlorophylls and protein decreased in drought stressed plants. However, proline content was increased in drought stressed plants and tends to decrease during the period of recovery. Keyvan (2010) [7] compared the bread wheat cultivars under drought stress at different stages and reported that with an increase in intensity of stress there was a decrease in total chlorophyll and increased proline content. Under severe water stress, the chlorophyll stability index (CSI) decreased with increase in water stress in most of the genotypes of maize (Meenakumari *et al.*, 2004) [14]. Zlatev and Stoyanov (2005) [24] suggested that proline accumulation in plants could be only useful as a possible drought injury sensor instead of its role in stress tolerance mechanism. Vendruscolo *et al.* (2007) [22] found that proline was involved in tolerance mechanisms against oxidative stress and this was the main strategy of plants to avoid detrimental effects of water stress. Laei (2012) [8] reported that in castor, the highest protein percentage of 26.37 per cent was recorded when drought stress was for 10 days compared to 5 days drought stress (22.27 %). Karimisara *et al.* (2012) [6] reported that water deficit in castor caused decreased concentration of soluble protein. Sharathkumar *et al.* (2010) [19] stated that higher castor equivalent yield (2380 kg ha^{-1}) was obtained in paired row systems of castor intercropped with clusterbean in 2:4 row proportions.

Materials and methods
Field experiments were conducted during *rabi* 2011-12 and 2012 -13 in farmer's field at Kokalai village, Namakkal district to study the effect of different drip irrigation levels with

different fertilizer levels on castor under onion intercropping system with split plot design and replicated thrice. Castor hybrid Yethapur Castor hybrid (YRCH 1) and onion crop (CO 3) was used for study purpose. The soil of the experimental site was texturally classified under sandy loam with 18.76 per cent field capacity, 7.74 per cent permanent wilting point, bulk density 1.04 (g cc^{-1}) and good drainage capacity. The soil pH was 8.49, organic carbon content 0.23 per cent and EC 0.12 dsm^{-1}. The initial soil nutrient status was 187.5 kg N, 20.3 kg P_2O_5 and 352.5 kg K_2O ha^{-1}.

The treatment comprised of three levels of irrigation regimes {drip irrigation at 40, 60 and 80 per cent cumulative pan evaporation (CPE)} and six levels of fertilizer (F_1: 75 % RDF as conventional fertilizer (CF); F_2: 75 % RDF as water soluble fertilizer (WSF); F_3: 75 % RDF (75 % CF + 25 % WSF); F_4: 100 % RDF as conventional fertilizer (CF); F_5: 100 % RDF as water soluble fertilizer (WSF); F_6: 100 % RDF (75 % CF + 25 % WSF) and surface irrigation with 100 per cent recommended dose of fertilizer as control.

The recommended dose of fertilizer was 60:30:30 kg NPK ha^{-1}. N and K were supplied through drip fertigation and full dose of P was supplied as basal in the form of single super phosphate under conventional fertilizer application. In the case of water soluble fertilizer, (poly feed -19:19:19 kg NPK ha^{-1}) was supplied through drip fertigation as nutrient sources for castor + onion intercrop.

For surface irrigation treatment, full dose of phosphorus (30 kg ha^{-1}), 50 per cent of nitrogen (30 kg ha^{-1}) and potassium (15 kg ha^{-1}) were applied as basal in the form of urea, single super phosphate and muriate of potash and remaining 50 per cent N and K (30: 0: 15 kg) were top dressed in two equal split at 30 and 60 day after sowing. Irrigation was supplied IW/ CPE ratio of 0.75 (66.6 mm) for surface irrigation.

Drip system was laid out in such a way that the main pipe was connected with head unit. The main line was divided into three sub line having separate controlling valves for I_1, I_2 and I_3 drip irrigation levels. Lateral lines were connected with sub main at a distance of 150 cm in a normal planting. The drippers were placed at a distance of 60 cm spacing. Castor crop hybrid (YRCH 1) was sown at a spacing of 150 x 120 cm. Onion intercrop (CO 3) was sown at either side of castor with the spacing of 30 x 10 cm. The crop was sown in the second fortnight of October during *rabi*, 2011-12 and first week of October during 2012-13, respectively. The drip irrigation schedule was started 15 days after sowing up to 150 days. The drip irrigation was given at 3 days intervals based on USWP open pan evaporimeter. Daily pan evaporation was measured with a help of pan evaporimeter and the cumulative of three days were calculated for water requirement under drip system. Water requirement of the crop was worked out by using the formula:

$WRc = CPE \times Kc \times Kp \times Wp \times A$

Where, WRc - Computed water requirement (litre $plant^{-1}$), CPE - cumulative pan evaporation for three days (mm), Kp - Pan factor (0.8), Kc - Crop factor {Initial stage (0 - 25 days) - 0.35; Developmental stage (26 - 60 days) - 1.15; Mid stage (61 - 130 days) - 1.15 and final stage (131 - 180 days) - 0.55} Wp - Wetting percentage and A - Area per plant. At 45 DAS, growth character of castor and onion was recorded and yield attributing character was collected at 90 DAS on randomly selected five plants. Castor yield on primary spike was harvested at 90 DAS, and next three picking (30 days interval) were followed within the duration of castor crop (180 days). Onion was harvested at maturity (90 DAS) and marketable onion was recorded for estimating the castor equivalent yield. The castor equivalent yield of intercropping system was computed by converting the yield of intercrops into castor seed equivalent on the basis prevailing market price.

Data collection and analysis

In order to determine the time course of electrolyte leakage during sample washing, the uppermost fully expanded leaf blade of fresh castor crop were collected for analysis as per the method of Leopold *et al*. (1981) [10]. Samples were collected at 45, 90 and 135 days after sowing for analysis.

Samples were collected at 45, 90 and 135 days after sowing for analysis of biochemical parameters *viz.*, chlorophyll content, chlorophyll stability index, proline and soluble protein. Chlorophyll content in the leaves of castor was determined by spectrophotometer as per the (Acetone or Arnon) method suggested by Holm (1954) [4]. Chlorophyll stability index was determined to assess the drought tolerance of castor methods followed by Holm (1954) [4]. Free proline content was determined calorimetrically in fully expanded 3rd to 5th fresh leaves (Bates *et al*., 1973) [1]. Soluble protein was estimated by following the method of Lowry *et al*. (1951) [11] using defatted bovine serum albumin (fraction V, Sigma) as standard. The data on various parameters studied during the course of investigation were statistically analysed, applying the technique of analysis of variance and regression analysis as suggested by Panse and Sukhatme (1978) [17]. Fisher's method of analysis of variance was applied for analysis and interpretation of data.

Result and Discussion

During *rabi*, 2011 - 12 and 2012 - 13, drip irrigation regimes exerted significant influence on biochemical parameter of castor crops.

At higher water stress (40 per cent CPE) showed significantly higher percentage of leakage (82.0, 83.2 in early stage, 79.6, 86.2 in mid stage and 76.7, 83.0 in late stage of castor crop during 2011 - 12 and 2012 - 13, respectively) and at 75 cent RDF as CF of 72.7 at vegetative stage, 69.3 at primary spike stage and 68.2 at tertiary spike stage during 2011 -12 and similar trend was noticed during the 2012-13, respectively. Low water stress (80 per cent CPE) recorded minimum per cent leakage of 71.0, 78.0 at early stage, 68.1, 81.3 at mid stage and 66.2, 80.1 at late stage of crop during both the years, respectively. Higher per cent of membrane integrity 82.2, 82.5 and 77.6 was recorded at 100 per cent RDF as WSF in 2011 -12 and same trend was noticed during 2012- 13, respectively (Table 1).

Drip irrigation at 80 per cent CPE showed increased total chlorophyll content (3.46, 3.53, 3.06 and 3.44, 3.47, 3.38 mg g^{-1} in all growth stages during 2011 - 12 and 2012-13 compared to stress plant (40 per cent CPE). Fertilizer at 100 per cent RDF as WSF significantly recorded higher total chlorophyll content (3.51, 3.56 and 3.12 mg g^{-1} at 45, 90 and 135 DAS during 2011 -12) compared to other fertilizer levels. Similar trend was recorded during 2012 -13 respectively (Table 1).

Drip irrigation at 40 per cent CPE significantly recorded lower chlorophyll stability index (CSI) value of 81.8, 82.2 and 81.7 per cent at 45, 90 and 135 DAS followed by 60 per cent CPE during 2011 - 12. The same trend was noticed during 2012 -13. Fertilizer application at 100 per cent RDF as WSF registered higher CSI value 85.0, 85.8 and 84.7 at 45, 90 and 135 DAS during 2011-12 and 85.4, 86.4 and 83.9 per cent during 2012- 13, respectively (Table 2).

Proline content increased from vegetative to primary spike stage and then declined at tertiary spike stages of castor in both the years. Drip irrigation at 40 per cent CPE showed increase in proline content of 7.40, 7.55 mg g^{-1} at early stage; 7.71, 10.61 mg g^{-1} at mid stage; 9.60, 11.84 mg g^{-1} at late stage during 2011- 12 and during 2012- 13, respectively. Significantly higher accumulation of proline was observed at 75 per cent RDF as CF (7.25, 7.51 and 8.68 mg g^{-1} at 45, 90 and 135 DAS during 2011-12 and 6.95, 9.83 and 10.65 mg g^{-1} during 2012 -13 respectively (Table 2).

Water stress at 40 per cent CPE showed lower soluble protein content of 22.6, 23.5, 22.4 and 23.7, 25.6, 23.8 mg g^{-1} at 45, 90 and 135 DAS during 2011 - 12 and 2012 - 13, respectively and at 80 per cent CPE the soluble protein content was higher in both the years. Nutrient at higher concentration (100 per cent RDF as WSF) recorded higher soluble protein content at 45, 90 and 135 DAS value of 27.3, 28.3, 27.3 during 2011 – 12 and 27.8, 31.6, 29.9 mg g^{-1} during 2012 - 13, respectively (Table 3).

Drip irrigation at 80 per cent CPE of castor + onion intercrop recorded significantly higher castor equivalent yield (4866 kg ha^{-1} during 2011-12 and 4565 kg ha^{-1} during 2012- 13 respectively) compared to 60 per cent CPE (4176 and 3942 kg ha^{-1}) during both the years. Fertilizer at 100 per cent RDF through WSF registered higher CEY of 5582 kg ha^{-1} and 5003 kg ha^{-1} during 2011-12 and 2012 - 13, respectively followed by 100 per cent RDF (75 % CF + 25 % WSF) and 100 per cent RDF through CF during both the years. Lower castor equivalent yield of 3986 and 3420 kg ha^{-1} was recorded under drip fertigation at 40 per cent CPE and 3938 and 3586 kg ha^{-1} with 75 per cent RDF through CF during 2011 - 12, and 2012 - 13, respectively (Table 3).

Table 1: Effect of drip fertigation on cell membrane integrity (per cent of leakage) and total chlorophyll content (mg g^{-1}) of castor

Treatments	Cell membrane integrity						Total chlorophyll					
	45 DAS		90 DAS		135 DAS		45 DAS		90 DAS		135 DAS	
	2011 - 12	2012 - 13	2011 - 12	2012 - 13	2011 - 12	2012 - 13	2011 - 12	2012 - 13	2011 - 12	2012 - 13	2011 - 12	2012 - 13
Drip Irrigation regimes												
I_1 – 40 % CPE	82.0	83.2	79.6	86.2	76.7	83.0	2.96	2.76	3.07	3.02	2.78	3.00
I_2 – 60 % CPE	74.8	80.9	71.8	83.2	70.4	81.7	3.27	3.20	3.31	3.24	2.95	3.21
I_3 – 80 % CPE	71.0	78.0	68.1	81.3	66.2	80.1	3.46	3.44	3.53	3.47	3.06	3.38
S.Ed	0.43	0.17	0.47	0.22	0.38	0.13	0.02	0.03	0.02	0.01	0.01	0.03
C. D. (P=0.05)	1.20	0.46	1.30	0.60	1.06	0.37	0.05	0.09	0.05	0.04	0.03	0.08
Fertilizer levels												
F_1 - 75% RDF as CF	72.7	78.5	69.3	81.4	68.2	79.9	3.02	2.97	3.14	3.15	2.82	3.09
F_2 - 75% RDF as WSF	77.2	81.2	74.8	84.6	72.2	82.3	3.31	3.19	3.36	3.28	2.97	3.26
F_3 - 75 % RDF (75% CF + 25% WSF)	74.8	79.9	71.9	82.6	69.8	81.2	3.23	3.08	3.30	3.23	2.89	3.18
F_4 - 100 % RDF as CF	79.0	83.1	76.6	85.6	74.2	82.9	3.36	3.29	3.40	3.33	3.04	3.25
F_5 - 100 % RDF as WSF	82.2	85.4	82.5	86.9	77.6	83.8	3.51	3.49	3.56	3.56	3.12	3.42
F_6 - 100 % RDF (75% CF + 25% WSF)	80.0	84.5	78.1	86.3	75.9	83.4	3.43	3.35	3.48	3.43	3.05	3.34
S.Ed	0.49	0.22	0.51	0.25	0.30	0.17	0.02	0.05	0.02	0.03	0.02	0.02
C. D. (P=0.05)	1.00	0.45	1.04	0.52	0.62	0.34	0.03	0.11	0.04	0.05	0.03	0.04
Surface irrigation +100 % RDF as CF	75.2	81.6	73.8	83.6	71.3	82.1	3.19	3.15	3.28	3.23	2.95	3.17

Table 2: Effect of drip fertigation on chlorophyll stability index (%) and proline content (mg g^{-1}) of castor

Treatments	Chlorophyll stability index (%)						proline content (mg g^{-1})					
	45 DAS		90 DAS		135 DAS		45 DAS		90 DAS		135 DAS	
	2011 - 12	2012 - 13	2011 - 12	2012 - 13	2011 - 12	2012 - 13	2011 - 12	2012 - 13	2011 - 12	2012 - 13	2011 - 12	2012 - 13
Drip Irrigation regimes												
I_1 – 40 % CPE	81.8	81.6	82.2	82.3	81.7	80.1	7.40	7.55	7.71	10.61	9.60	11.84
I_2 – 60 % CPE	82.5	82.5	83.2	83.3	82.6	80.9	6.84	6.45	6.99	9.27	7.56	9.62
I_3 – 80 % CPE	83.0	83.1	84.5	83.9	83.2	82.9	6.44	5.69	6.74	8.15	6.91	8.40
S.Ed	0.05	0.08	0.21	0.11	0.08	0.14	0.10	0.07	0.04	0.12	0.24	0.14
C. D. (P=0.05)	0.14	0.22	0.58	0.30	0.22	0.39	0.28	0.20	0.11	0.33	0.66	0.40
Fertilizer levels												
F_1 - 75% RDF as CF	80.9	80.5	82.1	81.7	81.2	79.9	7.25	6.95	7.51	9.83	8.68	10.65
F_2 - 75% RDF as WSF	83.3	83.1	83.8	83.6	83.0	81.8	6.82	6.38	7.02	9.17	7.91	0.61
F_3 - 75 % RDF (75% CF + 25% WSF)	81.8	82.2	82.9	82.8	82.3	81.0	7.02	6.68	7.20	9.56	8.12	10.19
F_4 - 100 % RDF as CF	83.8	83.7	84.3	84.4	83.4	82.4	6.49	6.24	6.85	8.81	7.39	9.36
F_5 - 100 % RDF as WSF	85.0	85.4	85.8	86.4	84.7	83.9	6.07	5.88	6.46	7.83	6.57	8.70
F_6 - 100 % RDF (75% CF + 25% WSF)	84.4	84.3	84.9	85.3	83.8	83.2	6.28	6.13	6.64	8.46	6.93	9.07
S.Ed	0.10	0.11	0.20	0.17	0.09	0.16	0.19	0.11	0.06	0.11	0.10	0.18
C. D. (P=0.05)	0.20	0.22	0.41	0.35	0.19	0.32	0.38	0.23	0.12	0.23	0.21	0.37
Surface irrigation +100 % RDF as CF	82.1	81.9	83.4	83.4	82.4	81.4	6.78	6.73	7.16	8.79	7.58	9.13

Table 3: Effect of drip fertigation on soluble protein (mg g^{-1}) and castor equivalent yield (CEY)(kg ha^{-1}) of castor

Treatments	Soluble protein (mg g^{-1})						Castor equivalent yield (kg ha^{-1})					
	45 DAS		90 DAS		135 DAS		Castor yield		Onion yield		CEY	
	2011 - 12	2012 - 13	2011 - 12	2012 - 13	2011 - 12	2012 - 13	2011 - 12	2012 - 13	2011 - 12	2012 - 13	2011 - 12	2012 - 13
Drip Irrigation regimes												
I_1 – 40 % CPE	22.6	23.7	23.5	25.6	22.4	23.8	1526	1134	3443	3200	3986	3420
I_2 – 60 % CPE	23.7	24.8	25.3	27.2	24.0	25.7	1636	1527	3555	3380	4176	3942
I_3 – 80 % CPE	25.7	26.2	26.3	28.4	25.1	27.3	2037	1918	3960	3706	4866	4565
S.Ed	0.25	0.13	0.11	0.16	0.12	0.36	43	31	36	70	71	64
C. D. (P=0.05)	0.71	0.37	0.30	0.46	0.34	0.99	128	86	99	195	198	177
Fertilizer levels												
F_1 - 75% RDF as CF	22.0	23.5	23.5	25.1	22.0	24.1	1580	1346	3301	3136	3938	3586
F_2 - 75% RDF as WSF	24.7	25.6	25.7	27.4	24.4	26.2	1709	1535	3563	3417	4254	3976
F_3 - 75 % RDF (75% CF + 25% WSF)	23.4	24.4	24.4	26.2	23.4	24.6	1697	1504	3403	3278	4128	3845
F_4 - 100 % RDF as CF	25.8	26.1	26.5	29.5	25.6	27.4	1946	1721	4345	3883	5049	4495
F_5 - 100 % RDF as WSF	27.3	27.8	28.3	31.6	27.3	29.9	2197	2077	4739	4097	5582	5003
F_6 - 100 % RDF (75% CF + 25% WSF)	26.5	27.0	27.4	30.4	26.4	28.4	2118	1907	4588	3990	5395	4757
S.Ed	0.27	0.20	0.20	0.26	0.19	0.37	26	26	41	41	49	40
C. D. (P=0.05)	0.55	0.40	0.41	0.54	0.39	0.75	53	52	83	83	100	82
Surface irrigation +100 % RDF as CF	24.2	24.8	25.1	26.7	23.6	25.1	2042	1881	3783	3572	4744	4432

Conclusion

The increased yield of trait under stress condition is caused by increase in number of mesophyll cells per unit area (Ober *et al*., 2005) [16]. The results obtained in the current study could be related to the rapid translocation of assimilates to the sink under the conditions of leaf death rate which occurs in stress condition.

Membrane disintegration is a primary symptom of both drought and heat injury, and membrane stability had been linked to drought and heat resistance (Blum and Ebercon, 1981) [2]. Plasma membrane stability can be used as a reliable measure of drought and heat resistance in plants (Ristic and Cass, 1993) [18]. Water stress at 40 per cent CPE caused membrane disintegration in castor hybrid YRCH 1 with more electrolyte leakage per cent as observed during both the years when compared to mild water stress at 80 per cent CPE. With reference to fertilizer levels, higher membrane leakage was noticed in 75 per cent RDF as CF in both the years of study. The combination of 40 per cent CPE with 75 per cent RDF as CF showed significantly higher electrolyte leakage. Disintegration of membrane is due to degradation of membrane lipids particularly that of polyunsaturated molecular species of galactolipids 18:3/18:3 MGDG (Monogalacto syldiacyl glygerol) and 18:3/18:3 (Digalacto syldiacyl glygerol) which were susceptible to drought. Hence intensity of degradation might have been higher in water stress at 40 per cent CPE when compared to 80 per cent CPE leading to accumulation of free fatty acids, which are likely to inhibit electron transport during photosynthesis (MVe-Akamba and Siegenthaler, 1980) [15]. Thus, its destruction under water deficit is deleterious to plant productivity.

Stress at any selected stage reduces chlorophyll contents and subsequently the castor yield remarkably. Irrigation at 40 per cent CPE recorded low level of chlorophyll contents compared to 80 per cent CPE irrigation level during 2011- 12 at different growth stages. Similar trend were also noticed in succeeding year of experimentation. Magudapathy (2000) [13] obtained similar results in sunflower. Normally the assimilation rate is maximum at physiological maturity stage of crop plants. Therefore lack of metabolites during this stage due to unfavourable conditions retarded chloroplast membrane synthesis (Henningsen, 1970) [3].

Chlorophyll stability index (CSI) is a measure of integrity of membrane or heat stability of the pigment under stress conditions (Kaloyereas, 1958) [5]. Higher chlorophyll stability index value recorded at various growth stages significantly helped the plant to withstand stress through better availability of chlorophyll. This leads to increase in photosynthetic rate and higher dry matter production in castor (Madhan Mohan *et al*., 2000) [12].

Unyayar *et al*. (2004) [20] reported that an increase in proline content was associated with soil moisture stress condition in sunflower. Any water conservation measures, mechanical or biological, or both coupled together will have an impact on the soil moisture stress thereby influencing upon the crop physiological behaviour. The present study on less water stress at 80 per cent CPE recorded lower proline content.

References

1. Bates LS, Waldren RP, Teare ID. Rapid determination of free proline for water-stress studies. Plant Soil, 1973; 39:205-207.
2. Blum A, Ebercon A. Cell membrane stability as a measure of drought and heat tolerance in wheat. Crop Sci. 1981; 21:43-47.
3. Henningsen KW. Macromolecular physiology of plastids VI. Chances in membrane structure associated with shifts in the absorption maxima of the chlorophyllus pigments. J. Cell Sci. 1970; 7:587-621.
4. Holm G. Chlorophyll mutation in barley. Acta Agric. Scand. 1954; 4:457-471.
5. Kaloyereas SA. A new method of determining drought resistance. Plant Physiol. 1958; 33:232-233.
6. Karimisara A, Hossein S, Jafar Masoud, Hassan M. Effect of water deficit and chitosan spraying on osmotic adjustment and soluble protein of cultivars. J. Stress Physiol. and Biochem. 2012; 8:161-169.
7. Kevyan S. The effect of drought stress on yield, relative water content, proline, soluble carbohydrates and chlorophyll of bread wheat cultivars. J. Anim. Plant Sci., 2010; 8(3):1051-1060.
8. Laei G. The effect of drought stress on grain yield and oil

rate and protein percentage of four varieties castor in climatic conditions of Damghan. J. Chemical Health Risks. 2012; 2(2):37-42.
9. Lauriano JA, Lidon FC, Carvalho CA, Campos PS, Matos MD. Drought effects on membrane lipids and photosynthetic activity in different peanut cultivars. Photosynthetica, 2000; 38:7-12.
10. Leopold AC, Musgrave ME, Williams KM. Solute leakage resulting from leaf desiccation. Plant Physiol., 1981; 68:1222-1225.
11. Lowry OH, Rose Brough LA, Randall BJ. Protein measurement with folin phenol reagent. J. Biol. Chem. 1951; 193:265-275.
12. Madhan Mohan M, Lakshmi Narayanan S, Ibrahim SM. Chlorophyll Stability Index (CSI): Its impact on salt tolerance in rice. Int. Rice Res. Notes, 2000; 25:38-39.
13. Magudapathy K. Physiological management of sunflower for enhancing productivity under stress condition. M. Sc., (Ag.) Thesis, submitted to Tamil Nadu Agricultural University, Coimbatore, India, 2000.
14. Meenakumari S, Dass Y, Pawan A. Physiological parameters governing drought tolerance in maize. Indian J. Plant Physiol. 2004; 9:203-207.
15. Mve-Akamba L, Siegenthaler PA. Effect of l'acide linolenique sur la photosynthese - dechloroplastes intacts de feuilles d'Epinard. Physiol. Veg. 1980; 18:689-701.
16. Ober ES, Bloa ML, Clark CJA, Royal A, Jaggard KW, Pidegon JD. Evaluation of physiological triats as indirect selection criteria for drought tolerance in sugar beet. Field Crop Res. 2005; 91:231-249.
17. Panse VG, Sukhatme PV. Statistical methods for agricultural workers, II Edn. ICAR, New Delhi, India, 1978.
18. Ristic Z, Cass DD. Dehydration avoidance and damage to the plasma and thyllakoid membranes in lines of maize differing in endogenous levels of abscisic acid. J. Plant Physiol. 1993; 142:759-763.
19. Sharathkumar HC, Mudulagiriyappa H, Nanjappa V, Ramachandrappa BK. Productive performance of castor (*Ricinus communis* L.) based intercropping systems under rainfed conditions of central dry zone in Karnataka. Mysore J. Agric. Sci. 2010; 44(33):481-484.
20. Unyayar S, Keles Y, Unal E. Proline. ABA levels in two sunflower genotypes subjected to water stress. Bulg. J. Plant Physiol. 2004; 30(3-4):34-47.
21. Vainola A, Repo T. Impedance spectroscopy in frost hardiness evaluation of Rhododendron leaves. Ann. Bot. 2000; 41:827-832.
22. Vendruscolo ACG, Schuster I, Pileggi M, Scapim CA, Molinari HBC, Marur CJ *et al*. Stress induced synthesis of proline confers tolerance to water deficit in transgenic wheat. J. Plant Physiol. 2007; 164(10):1367-1376.
23. Weiss EA. Castor, Sesame and Safflower. Leonard hill, London, 1971.
24. Zlatev Z, Stoyanov Z. Effect of water stress on leaf water relations of young bean plants. J. Central Eur. Agric. 2005; 6(1):124.