**ANNEXURE - VII**

**INDIAN COUNCIL OF AGRICULTURAL RESEARCH**

**FINAL RESEARCH PROJECT REPORT (RPP- III)**

**(For Guidelines Refer ANNEXURE – XI(G))**

**PROJECT REPORT (RPP- III)**

1. Institute Project Code: 104-7
2. Project Title: ”Studies on drought tolerance, water use efficiency and source – sink relationships in castor**”**
3. Key Words: Drought, WUE, source, sink, castor
4. (a) Name of the Lead Institute: Indian Institute of Oilseeds Research (IIOR), formerly DOR (b) Name of Division/ Regional Center/ Section: Crop Production (Plant Physiology)
5. (a) Name of the Collaborating Institute(s): NA

(b) Name of Division/ Regional Center/ Section of Collaborating Institute(s)

1. Project Team(Name(s) and designation of PI, CC-PI and all project Co-PIs, with time spent)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| S. No. | Name, designation and institute | Status in the project (PI/CC-PI/ Co-PI) | Time spent (%) | Work components assigned to individual scientist |
| 1 | P. Lakshmamma, Principal Scientist, IIOR, Hyderabad | PI | 60 | Planning and execution of the experiment, data analysis, report writing |
| 2 | Lakshmi Prayaga, Principal Scientist, IIOR, Hyderabad | Co-PI | 40 | Physiological and biochemical estimations |

1. Priority Area: Castor- 6. Studies on drought tolerance
2. Project Duration: Date of Start : June, 2009 Date of Completion : May, 2015

1. a. **Objectives:**

* To screen important germplasm, pistillate lines and breeding lines for identifying traits related to WUE and also root characters
* To study source-sink relationships

b. **Practical utility**:

Castor (*Ricinus communis* L.) is grown in Andhra Pradesh mainly as rainfed crop in marginal and sub marginal shallow soils with low inputs. The crop experiences water stress at different stages of crop growth depending on rainfall pattern during that season which results in reduced yields. Under drought conditions, yield is determined by Water use efficiency (WUE). This character showed significant genetic variability and also has heritability. Traits like specific leaf area (SLA), SPAD chlorophyll meter reading (SCMR) are alternate approaches for measuring WUE. Among the several factors contributing to drought resistance, root characters are particularly important as they are responsible for water mining from soil and thus maintain the plant water status. Measuring different root characters along with other WUE traits in specially constructed root structures helps in identifying genotypes with better root growth, and with better WUE traits. Genetic variability for traits related to drought tolerance is scattered in germplasm accessions and may be productive when incorporated to high yielding agronomic back ground. Selection for these traits in a breeding program could then result in more accurate targeting of factors limiting yield there by increasing the rate of yield improvement. Field screening of selected lines along with susceptible checks helps in identifying lines with drought tolerance which can be used in breeding for drought tolerance.

Castor is infested with a number of insect pests at different phenological stages of the crop in India. Heavy foliage loss from major defoliating insects like semilooper, tobacco caterpillar, Bihar hairy caterpillar is very common and is quite high in south India especially during *kharif.* Because of its indeterminate growth habit, it is capable of recovering such damage. No research information is available on its ability to recover the extent of foliage loss due to insect damage so as to initiate appropriate and economic insect management strategies. Therefore, quantifyingyield decreases resulting from defoliation on entire plant or young leaves may play an importantrole in predicting yields, establishing thresholds for pesticidetreatments, plan the feed for eri silk worm rearing.

Primary and secondary spikes are major contributors to castor yields. Quantification of the extent of compensation from other orders if one order is lost due to *Botryris* or capsule borer helps in planning the pest management strategy.

As water is becoming scarce, genotypes with better drought tolerance traits help the farmer to get more yield in rainfed conditions from castor crop. Understanding of source sink limitations help in developing castor genotypes with short duration and suitable for intercropping. Eri silk worm rearing with castor leaves based on the crop’s ability to recover the extent of foliage loss helps the farmer to have additional benefits from silk industry.

**10:** Final Report on the Project (materials and methods used, results and discussion, objective wise achievements and conclusions)

**(Final report enclosed as Annexure)**

**Objective-wise achievements:**

|  |  |  |  |
| --- | --- | --- | --- |
| **Objective** | **Activity** | **Methodology** | **Acheivements** |
| 1. To screen important germplasm, pistillate lines and breeding lines for identifying traits related to WUE and also root characters | 1.Screening castor germplasm and pistillate lines for water use efficiency (WUE) and root traits | A total of 160 genotypes (110 germplasm and 60 breeding lines) were screened in specially constructed root structures | 60 germplasm and 11 breeding lines with good root and WUE traits were selected for use in breeding programs |
| 2. Study of root growth under control and stress conditions (root structure and field study) | Two contrasting genotypes for root growth were studied in root structure and field conditions under irrigated and stress conditions | Root length reduction was not much due to stress. But root volume, dry weight and shoot growth reduced with stress and the % reduction was less in poor root genotype.  With drought stress in field, the seed yield reduction was more in poor root genotype |
| 3.Confirmation of drought tolerance of castor lines with better root traits in field conditions | 36 germplasm lines along with checks were screened for drought tolerance in field by imposing drought stress from 30-90 DAS | 12 germplasm lines with drought tolerance in field were selected |
| 4. Screening identified germplasm lines with drought tolerance under *kharif* condition | 6 germplasm lines with known drought tolerance were studied for their performance in kharif in field. | RG 298 and RG 1826 performed better in kharif compared to other lines with reduced duration |
| 5. Seedling tolerance of castor genotypes with desirable root traits for drought, temperature and salinity | Selected germplasm with good root traits were screened in lab for germination in drought (42 genotypes with PEG), salinity (6 lines with NaCl) and seedling tolerance to temperature (44 lines with TIR technique) | The best lines with good root growth, field tolerance to drought, seedling tolerance to drought and temperature include: RG 72, RG 89 and RG 111 |
| 6. Effect of Trichoderma on drought stress alleviation in castor | Seed treated with 10 trichoderma isolates @10g/kg were screened for drought tolerance in field by imposing water stress from 30-90 DAS | Trichoderma seed treatment with T673 and T7316 isolates improved total seed yield in drought stressed plots followed by TV2, TV5 and TA2 |
| 7. Screening cultivated varieties and hybrids of castor for temperature tolerance | 10 hybrids, 4 varieties were sown for 2 years at 4 dates of sowing (Nov. 16th to Jan. 18th ) to select temperature tolerant hybrids and varieties | Genotypes selected for temperature tolerance with delayed sowings include Gauch-1, GCH-2, GCH-5 and DCH-519 |
| 2.To study source-sink relationships | 1.Yield reduction with defoliation of young leaves in castor | Defoliation of young leaves @ 0, 25,50% from top at spike initiation of different order branches on yield reduction was studied for 2 years | Removal of young leaves up to a maximum of 25% in any one or two orders will not adversely affect the seed yield  And can be used for profitable rearing of eri silk worm |
| 2.Effect of nipping of spikes on seed yield | Nipping of different order spikes at initiation or at full expansion on yield compensation was studied | Total seed yield was on par with control in nipping of any one order spikes at spike initiation or at full expansion which shows the extent of compensation in castor |
| 3. Leaf fall quantification in castor | Fallen leaf weight was quantified by collecting the fallen leaves from 10 plants at weekly intervals by tagging leaves of each genotype with different color ribbons | Fallen leaf weight percent in total dry matter ranged from 15 – 27 with a mean of 20%.  Equation for estimation of TDM with senescing/fallen leaf weight was derived using linear method  TDM with fallen leaf weight = 1.229 X TDM without fallen leaf weight |
| 4.Selection of castor parents with high harvest index | 3 selected parents with high HI were sown for confirmation | K12-86-2 recorded 33.7% HI followed by 48-1 (31.3) and K1298-3 - (30.4%) |

**11**: Financial Implications (` in Lakhs)

**11.1** Expenditure on

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S.**  **No.** | Expenditure on | **2009-10** | **2010-11** | **2011-12** | **2012-13** | **2013-14** | **2014-15** | **Total**  **(lakhs)** |
| a | Manpower | 11.1 | 11.8 | 13.1 | 15.5 | 19.4 | 24.3 | 95.2 |
| b | Research/Recurring Contingencies | 0.60 | 0.75 | 0.75 | 0.5 | 0.75 | 0.75 | 4.1 |
| c | Non-Recurring Cost (Including cost of equipment) | 0.0 | 0.0 | 0.0 | 0.0 | 1.0\* | 3.0\*\* | 4.0 |
| d | Any Other Expenditure Incurred | - | - | - | - | - | - | 0.0 |
|  | Total (Rs in lakhs) | 11.70 | 12.55 | 13.85 | 16.0 | 21.15 | 28.05 | **103.3** |

\* pH meter, EC meter, vernier callipers \*\* SPAD chlorophyll meter, Precision balance

* 1. Total Expenditure: **Rs 103.3 lakhs**

**12**: Cumulative Output

* 1. Special attainments/innovations:
* Use of selected drought tolerant germplasm and breeding lines for incorporation of traits for high root, WUE, drought, temperature tolerance and HI into agronomically superior background helps in developing genotypes with increased productivity under rainfed conditions.
* Removal of young leaves up to a maximum of 25% in any one or at the most two orders is recommended for profitable rearing of eri silk worm without any concomitant yield reduction in castor.
* Factor for leaf fall quantification to work out total dry matter for selection of genotypes with high HI
  1. List of Publications (one copy each to be submitted if not already submitted)
     1. **Research papers**

**Objective 1:** To screen important germplasm, pistillate lines and breeding lines for identifying traits related to WUE and also root characters

1. Lakshmi Prayaga and **Lakshmamma P** (**2009**): New technique for root studies. *DOR News Letter*, **14** (4): 1-2
2. **Parvathaneni Lakshmamma**, Lakshmi Prayaga, and Chunduri Sarada (**2010**): Evaluation of Castor (*Ricinus communis* L.) Germplasm for Water Use Efficiency (WUE) and Root Characters. *Journal of Plant genetic resources*, **23** (3): 276-279.
3. **P.Lakshmamma**, Lakshmi Prayaga, K. Anjani and C. Lavanya (**2010**). Identification of castor genotypes for water use efficiency (WUE) and root traits. *Journal of Oilseeds Research* (special issue), 27: 187-189
4. **Lakshmamma P** and Lakshmi Prayaga (**2010**): Variability for water use efficiency traits and drought tolerance in castor ( *Ricinus communis* L.) germplasm lines. Journal of Oilseeds Research, 27 (1): 81-84
5. Sarada. C, P.Lakshmamma, Lakshmi Prayaga and K. Alivelu (2010). Canonical correlation analysis for determination of interrelationships between root and shoot characters in castor. *Journal of Oilseeds Research*(special issue),27: 114-116
6. **Lakshmamma**, Lakshmi Prayaga and C. Sarada (**2013**): Genetic variability for root, shoot and water use efficiency traits in castor (*Ricinus communis* L.). *Journal of Oilseeds Research*, 30 (1): 85-89.
7. P.Lakshmamma, Lakshmi Prayaga, C. Lavanya and C. Sarada (2014): Genetic diversity, variability and heritability for root, shoot and water use efficiency traits in castor (*Ricinus communis* L.) genotypes. *Indian Journal of Plant genetic Resources*, 27 (3): 230-237

**Objective 2:** **To study source-sink relationships**

1. Lakshmamma P, Lakshminarayana M, Lakshmi Prayaga, Alivelu K and Lavanya C (2009): Effect of defoliation on seed yield of castor (*Ricinus communis*). Indian Journal of Agricultural Sciences, 79 (8): 620-623.
2. Lakshmamma P, Lakshmi Prayaga, Lakshminarayana M, Alivelu K and Lavanya C (2009): Effect of source manipulation on yield of different spike orders in castor (*Ricinus communis* L.). *Journal of Oilseeds Research*, 26; 343-344
3. **P.Lakshmamma,** Lakshmi Prayaga, M.Lakshminarayana and K.Alivelu **(2010):** Source manipulation induced variation in dry matter partitioning to reproductive sink in castor (*Ricinus communis* L.) *Indian Journal of Plant Physiology*, **15** (3) 213-218
4. Lakshmi Prayaga, P.Lakshmamma and M. Lakshminarayana (2010). Contribution of upper leaves to seed yield of castor. *Journal of Oilseeds Research*(special issue), 27: 209-212

**Review article:**

Severino, L.S., D.L. Auld, M. Baldanzi, M.J.D. Cândido, G. Chen, W. Crosby, Tan D., X. He, **P. Lakshmamma**, C. Lavanya, O.L.T. Machado, T. Mielke, M. Milani, T.D. Miller, J.B. Morris, S.A. Morse, A.A. Navas A., D. J. Soares, V. Sofiatti, M.L. Wang, M.D. Zanotto, H. Zieler. (2012). A review on the challenges for increased production of castor. *Agronomy Journal* 104: 853-880.

* + 1. Reports/Manuals: Nil
    2. Working and Concept Papers: Nil
    3. Popular articles: Nil
    4. Books/Book Chapters: Nil
    5. Extension Bulletins: Nil
  1. Intellectual Property Generation

(Patents - filed/obtained; Copyrights- filed/obtained; Designs- filed/obtained: Nil

Registration details of variety/germplasm/accession if any)

* 1. Presentation in Workshop/Seminars/Symposia/Conferences

(relevant to the project in which scientists have participated)

1. **P. Lakshmamma**, Lakshmi Prayaga and C. Sarada (**2010**). Evaluation of castor germplasm for water use efficiency (WUE) and root characters. Poster presented in National Seminar on “Climate change and Rainfed Agriculture” from February 18-20, 2010 at CRIDA, Hyderabad, AP pp 155-157
2. P.Lakshmamma, Lakshmi Prayaga, K. Anjani and C. Lavanya (2010). Identification of castor genotypes for water use efficiency (WUE) and root traits. Poster presented in National Symposium on “Research and Development in Castor: Present status and future strategies” form October 22-23, 2010 at DOR, R.Nagar, Hyderabad.
3. Sarada C, **P.Lakshmamma**, Lakshmi Prayaga and K. Alivelu (**2010**).Canonical correlation analysis for determination of interrelationships between root and shoot characters in castor. .Poster presented in National Symposium on “Research and Development in Castor: Present status and future strategies” form October 22-23, 2010 at DOR, R.Nagar, Hyderabad
4. Lakshmi Prayaga and **P.Lakshmamma** (**2010**). Contribution of upper leaves to seed yield of castor. Poster presented in National Symposium on “Research and Development in Castor: Present status and future strategies” form October 22-23, 2010 at DOR, R.Nagar, Hyderabad
5. **P.Lakshmamma**, Lakshmi Prayaga, C. sarada and C. Lavanya (**2012**). Screening castor genotypes for water use efficiency (WUE) and root traits. Paper presented in National seminar on “.Physiological and Molecular Approaches for Development of Climate Resilient Crops” held during 12-14 December, 2012 at ANGRAU, Hyderabad.
6. **P.Lakshmamma**, Lakshmi Prayaga and K. Alivelu (**2015**). Selection of castor germplasm with good root traits for drought tolerance in field. Paper presented in 3rd International Plant Physiology Congress held at JNU, New Delhi from Dec 11 – 14, 2015
   1. Details of technology developed: Genotypes with good root, WUE traits and drought tolerance

(Crop-based; Animal-based, including vaccines; Biological – biofertilizer, biopesticide, etc; IT based – database, software; Any other – please specify)

* 1. Trainings/demonstrations organized**:** Nil
  2. Training received: Nil
  3. Any other relevant information : Nil

**13**: (a) Extent of achievement of objectives and outputs earmarked as per RPP-I

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Objective** | **Activity** | **Envisaged output of monitorable target(s)** | **Output achieved** | **Extent of Achievement (%)** |
| 1. To screen important germplasm, pistillate lines and breeding lines for identifying traits related to WUE and also root characters | 1.Screening castor germplasm and pistillate lines for water use efficiency (WUE) and root traits | Selection of germplasm and breeding lines with good root and WUE traits | 60 germplasm and 11 breeding lines with good root and WUE traits were selected for use in breeding programs | 100 |
| 2. Study of root growth under control and stress conditions (root structure and field study) | To see the effect of drought stress on root growth in good and poor root genotypes | Root length reduction was not much due to stress. But root volume, dry weight and shoot growth reduced with stress and the % reduction was less in poor root genotype.  With drought stress in field, the seed yield reduction was more in poor root genotype | 100 |
| 3.Confirmation of drought tolerance of castor lines with better root traits in field conditions | Selection of drought tolerant germplasm with good root traits in field | 12 germplasm lines with drought tolerance were selected by imposing drought stress from 30-90 DAS | 90  (Few genotypes died due to severe wilt infestation) |
| 4. Screening identified germplasm lines with drought tolerance under *kharif* condition | Selection of best drought tolerant genotypes among the selected in natural kharif condition | RG 298 and RG 1826 performed better in kharif compared to other lines with reduced duration | 100 |
| 5. Seedling tolerance of castor genotypes with desirable root traits for drought, temperature and salinity | Genotypes with desirable traits for germination and seedling tolerance to different stresses | The best lines with good root growth, field tolerance to drought, seedling tolerance to drought and temperature include: RG 72, RG 89 and RG 111 | 100 |
| 6. Effect of Trichoderma on drought stress alleviation in castor | Selection of best strains to alleviate drought stress | Trichoderma seed treatment with T673 and T7316 isolates improved total seed yield in drought stressed plots followed by TV2, TV5 and TA2 | 100 |
| 7. Screening cultivated varieties and hybrids of castor for temperature tolerance | Selection of temperature tolerant varieties and hybrids suitable for any season | Genotypes selected for temperature tolerance with delayed sowings include Gauch-1, GCH-2, GCH-5 and DCH-519 | 100 |
| 2.To study source-sink relationships | 1.Yield reduction with defoliation of young leaves in castor | To see the extent of yield reduction with young leaf defoliation for eri silk worm rearing | Removal of young leaves up to a maximum of 25% in any one or two orders will not adversely affect the seed yield  And can be used for profitable rearing of eri silk worm | 100 |
| 2.Effect of nipping of spikes on seed yield | To see the extent of compensation in next order spikes with capsule damage in lower order spikes | Total seed yield was on par with control in nipping of any one order spikes at spike initiation or at full expansion which shows the extent of compensation in castor | 100 |
| 3. Leaf fall quantification in castor | To record the % senescing leaf fall and factor for estimation of TDM with inclusion of fallen leaf weight | Fallen leaf weight percent in total dry matter ranged from 15 – 27 with a mean of 20%.  Equation for estimation of TDM and HI with senescing/fallen leaf weight was derived using linear method  TDM with fallen leaf weight = 1.229 X TDM without fallen leaf weight  HI with fallen leaf weight = 0.797 X HI without fallen leaf weight | 100 |
| 4.Selection of castor parents with high harvest index | To select breeding lines with high partitioning efficiency (HI) | K12-86-2 recorded 33.7% HI followed by 48-1 (31.3) and K12-98-3 (30.4%) | 100 |

(b) Reasons of shortfall, if any:

Data on drought tolerance of few genotypes could not be recorded due to severe wilt infestation

**14:** Efforts made for commercialization/technology transfer:

Parental lines (DCS 78,106,107, DPC 19) are being used in breeding programs.

**15**: (a) How the output is proposed to be utilized?

Germplasm lines with good root, drought tolerance (lab, field), and temperature tolerance were to be included in breeding programs. Selected parental lines are being used in breeding programs.

(b) How it will help in knowledge creation?

Though castor crop is known to be drought tolerant, studies about component traits contributing to drought tolerance were not carried out. Hence, the present project and the results obtained in this have contributed to knowledge on possible mechanisms of drought tolerance and also identification of genotypes with drought tolerance.

**16**: Expected benefits and economic impact (if any):

Breeding for tolerance to abiotic stresses is the need of the hour in changing climate scenario. Though it is very difficult as it is multi gene controlled, inclusion of the selected genotypes for drought, temperature, high HI, tolerance to biotic stresses and with agronomic superiority in terms of seed yield can be included in breeding varieties and hybrids with increased productivity for rainfed areas. Even if a nominal 10% yield advantage under rain fed conditions is envisaged with the genotypes that could be developed based on this project, it leads to yield advantage of 0.5Q / ha.

**17:** Specify whether the project requires submission of RPP-IV for up scaling of research output

No. But the identified genotypes with good root growth from this project will be used for developing inbreds in proposed new projects on castor germplasm and breeding lines

**18**: Future line of research work/other identifiable problems:

60 germplasm and 11 breeding lines were selected for good root traits and few of them were screened for drought using PEG induced stress and for temperature tolerance with Temperature Induction Response (TIR) technique) both during germination and seedling stage. These genotypes are being validated for the drought tolerance under field conditions. The remaining genotypes need to be screened for their lab and field performance to drought, temperature and salinity. Selection of germplasm, breeding lines with early vigor and high HI needed for popularizing castor for rice fallows. Differences in terminal drought tolerance of genotypes need to be studied as terminal drought stress due to cessation of monsoon is very common in farmer’s fields. These studies will be conducted in proposed new projects on breeding and germplasm along with trait specific inbred development.

**19**: Details on the research data (registers and records) generated out of the project deposited with the institute for future use:

Yes. Data books submitted to PME/TIO of the institute

**20**: Signature of PI, CC-PI(s), all Co-PIs

(P. Lakshmamma) (Lakshmi Prayaga)

(Project Leader]) (Co-PI)

**21**: Signature of Head of Division

(I Y L N Murthy)

(Head, Crop Production)

**22:** Observations of PME Cell based on Evaluation of Research Project after Completion

**23**: Signature (with comments if any along with rating of the project in the scale of 1 to 10

on the overall quality of the work) of JD (R)/ Director

(K.S. Varaprasad)

Director, ICAR-IIOR

**Annexure**

**10. Final Report on the Project** (materials and methods used, results and discussion, objective wise achievements and conclusions)

**Objective 1:** To screen important germplasm, pistillate lines and breeding lines for identifying traits related to WUE and also root characters

**1. Screening castor germplasm and pistillate lines for water use efficiency (WUE) and root traits**:

**(2009-10 to 2011-12)**

Root studies were conducted by growing plants in specially constructed raised structures on the ground. The height of the structure varies with the crop and depends on the depth to which the roots of the crop can penetrate. Castor genotypes were screened in 30 x 2.4 x 1.5m (L x B x H) structure which can accommodate 33 castor genotypes on either side. The structure has one central permanent wall with side collapsible walls that are constructed with hollow cement bricks and is secured by erecting wooden poles on either side which are held together tightly with a wire. Once the structure is filled with soil, it is watered regularly to allow compaction. When the bulk density of the structure reaches the bulk density of that of field, sowings were done and the castor plants were allowed to grow for 90-100days which coincide with the maximum root growth. On the day of harvest, the side walls were carefully removed and with a jet of water the roots were washed and various shoot observations like SCMR, SLA, LAI, TDM, plant height, leaf number, stem girth and root traits like length, volume, weight were recorded.

Leaf samples were sent for 13C and 18O estimation after drying as these characters give an idea about WUE. Promising genotypes for each of these characters were identified. Stem girth and TDM showed positive correlation (>0.70) with root volume and root dry weight. Hence lines with better root volume, dry weight, stem girth, LAI and TDM are considered as best lines for WUE and root traits. Based on an index developed using principal component analysis with these root and shoot characters, genotypes possessing best characters were identified. During 2009-2011, 160 genotypes of castor were evaluated for root characters. A total of 33 genotypes (23 germplasm, 10 breeding lines) with good root and WUE traits were selected. The list of germplasm and breeding lines selected from 2006-2011 along with their root growth (root volume, root dry weight) and shoot growth characters is given in Table 1a&b.

Table 1a: Root and shoot growth of selected germplasm lines (2006-2011)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Selected germplasm lines for root and WUE traits** | | | | | | | |
|  | **Entry name** | **Year** | **Root volume (cm3)** | **Root dry weight (g/pl.)** | **LAI** | **Stem girth (cm)** | **TDM(g/pl.)** |
| 1 | RG 27 | 2009-10 | 216.5 | 40.6 | 1.44 | 8.7 | 218 |
| 2 | RG 72 | 2010-11 | 545 | 91.9 | 3.17 | 11.9 | 609 |
| 3 | RG 82 | 2006-07 | 279 | 41.1 | 2.50 | 8.8 | 371 |
| 4 | RG 89 | 2006-07 | 203 | 33.9 | 2.40 | 8.9 | 286 |
| 5 | RG 111 | 2010-11 | 404 | 68.4 | 2.76 | 11.5 | 503 |
| 6 | RG 122 | 2006-07 | 233 | 39.7 | 3.30 | 10.1 | 341 |
| 7 | RG 152 | 2006-07 | 265 | 59.1 | 2.70 | 10.1 | 389 |
| 8 | RG 211 | 2006-07 | 206 | 35.7 | 3.30 | 9.8 | 362 |
| 9 | RG 240 | 2006-07 | 355 | 57.7 | 5.30 | 10.7 | 351 |
| 10 | RG 272 | 2006-07 | 273 | 48.0 | 3.10 | 11 | 384 |
| 11 | RG 282 | 2006-07 | 211 | 33.8 | 2.00 | 9.4 | 315 |
| 12 | RG 289 | 2010-11 | 429 | 79.6 | 3.04 | 9.8 | 523 |
| 13 | RG 298 | 2006-07 | 255 | 38.1 | 2.8 | 9.7 | 281 |
| 14 | RG 328 | 2010-11 | 330 | 56.3 | 2.25 | 9.5 | 441 |
| 15 | RG 373 | 2010-11 | 405 | 71.8 | 0.44 | 11.1 | 404 |
| 16 | RG 415 | 2010-11 | 432 | 78.9 | 3.42 | 11.2 | 468 |
| 17 | RG 539 | 2006-07 | 317 | 49.4 | 3.50 | 11.4 | 412 |
| 18 | RG 627 | 2006-07 | 279 | 47.4 | 3.20 | 11.1 | 354 |
| 19 | RG 786 | 2006-07 | 334 | 46.5 | 2.80 | 10.7 | 333 |
| 20 | RG 941 | 2006-07 | 209 | 41.3 | 2.20 | 8.6 | 281 |
| 21 | RG 1437 | 2008-09 | 355 | 63.5 | 2.78 | 11.9 | 448 |
| 22 | RG 1450 | 2007-08 | 310.5 | 55.6 | 4.94 | 10.0 | 422 |
| 23 | RG 1463 | 2008-09 | 314 | 54.5 | 4.47 | 10.4 | 421 |
| 24 | RG 1464 | 2007-08 | 135.0 | 24.2 | 1.61 | 7.8 | 181 |
| 25 | RG 1494 | 2008-09 | 310 | 122.0 | 2.54 | 10.4 | 465 |
| 26 | RG 1611 | 2007-08 | 246.5 | 44.2 | 4.57 | 9.3 | 395 |
| 27 | RG 1614 | 2008-09 | 584 | 89.0 | 3.71 | 11.1 | 500 |
| 28 | RG 1617 | 2010-11 | 616 | 99.7 | 2.20 | 11.3 | 472 |
| 29 | RG 1618 | 2009-10 | 226.0 | 34.7 | 1.74 | 8.9 | 145 |
| 30 | RG 1645 | 2008-09 | 380 | 63.6 | 3.08 | 10.0 | 429 |
| 31 | RG 1661 | 2007-08 | 377.3 | 41.7 | 2.85 | 10.0 | 357 |
| 32 | RG 1667 | 2006-07 | 202 | 28.2 | 1.7 | 9.1 | 258 |
| 33 | RG 1673 | 2009-10 | 225.0 | 37.0 | 1.55 | 8.4 | 250 |
| 34 | RG 1759 | 2010-11 | 585 | 101.6 | 3.34 | 10.9 | 502 |
| 35 | RG 1826 | 2007-08 | 268.8 | 51.6 | 4.30 | 9.2 | 427 |
| 36 | RG 1922 | 2008-09 | 411 | 65.9 | 2.27 | 10.7 | 433 |
| 37 | RG 1941 | 2008-09 | 487 | 85.3 | 2.64 | 11.5 | 629 |
| 38 | RG 1963 | 2009-10 | 216.5 | 37.1 | 1.80 | 7.4 | 213 |
| 39 | RG 2048 | 2006-07 | 307 | 45.6 | 2.20 | 9.7 | 313 |
| 40 | RG 2058 | 2008-09 | 276 | 44.7 | 7.64 | 10.0 | 497 |
| 41 | RG 2059 | 2007-08 | 181.0 | 28.4 | 3.31 | 8.1 | 230 |
| 42 | RG 2074 | 2009-10 | 258.5 | 43.2 | 2.43 | 8.9 | 226 |
| 43 | RG 2094 | 2009-10 | 231.5 | 38.0 | 2.66 | 8.2 | 210 |
| 44 | RG 2113 | 2008-09 | 429 | 71.2 | 3.29 | 12.2 | 409 |
| 45 | RG 2122 | 2007-08 | 328.0 | 54.6 | 4.08 | 9.9 | 453 |
| 46 | RG 2124 | 2009-10 | 371.5 | 56.7 | 2.70 | 8.5 | 341 |
| 47 | RG 2127 | 2008-09 | 546 | 94.8 | 3.22 | 11.7 | 501 |
| 48 | RG 2139 | 2008-09 | 557 | 92.9 | 4.57 | 11.0 | 502 |
| 49 | RG 2147 | 2009-10 | 282.5 | 31.1 | 2.02 | 8.4 | 212 |
| 50 | RG 2149 | 2007-08 | 391.3 | 69.3 | 5.50 | 11.2 | 638 |
| 51 | RG 2153 | 2009-10 | 204.5 | 37.6 | 3.05 | 8.4 | 316 |
| 52 | RG 2155 | 2009-10 | 244.0 | 46.6 | 3.83 | 8.3 | 372 |
| 53 | RG 2169 | 2009-10 | 304.5 | 50.3 | 4.10 | 8.9 | 277 |
| 54 | RG 2439 | 2010-11 | 450 | 68.0 | 3.16 | 10.2 | 397 |
| 55 | RG 2714 | 2007-08 | 374.8 | 54.2 | 4.01 | 10.0 | 415 |
| 56 | RG 2779 | 2010-11 | 392 | 62.2 | 2.10 | 8.8 | 340 |
| 57 | RG 2797 | 2007-08 | 262.5 | 47.9 | 2.69 | 10.5 | 312 |
| 58 | RG 2826 | 2007-08 | 254.0 | 46.9 | 2.63 | 9.9 | 317 |
| 59 | RG 2850 | 2007-08 | 263.0 | 49.9 | 3.29 | 10.2 | 379 |
| 60 | RG 3063 | 2007-08 | 353.0 | 62.4 | 4.87 | 10.8 | 430 |

Table 1b: Root and shoot growth of selected breeding lines (2006-2011)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Selected breeding lines for root and WUE traits** | | | | | | | |
|  | **Entry name** | **Year** | **Root volume (cm3)** | **Root dry weight (g/pl.)** | **LAI** | **Stem girth (cm)** | **TDM(g/pl.)** |
| 1 | DCS 78 | 2009-10 | 248 | 43.1 | 1.94 | 8.7 | 300 |
|  |  | 2010-11 | 132 | 21.5 | 1.94 | 6.9 | 218 |
|  |  | 2011-12 | 167 | 29 | 2.98 | 7.1 | 227 |
| 2 | DCS-99 | 2009-10 | 219 | 36.9 | 3.11 | 9.1 | 261 |
| 3 | DCS 107 | 2011-12 | 157 | 29.2 | 2.41 | 7.3 | 204 |
| 4 | DPC 19 | 2011-12 | 167 | 29.0 | 2.98 | 7.1 | 227 |
| 5 | DPC 20XDCS102 | 2011-12 | 135 | 22.5 | 2.29 | 6.6 | 266 |
| 6 | DPC 9 X DCS 9 | 2011-12 | 198 | 34.1 | 3.26 | 7.7 | 309 |
| 7 | DPC 9X DCS 78 | 2011-12 | 120 | 18.6 | 1.28 | 6.7 | 188 |
| 8 | DPC 9X RG1582 | 2011-12 | 140 | 24.8 | 1.81 | 6.6 | 216 |
| 9 | PBMC 2 | 2011-12 | 175 | 32.5 | 4.16 | 6.8 | 219 |
| 10 | PBMC 5 | 2011-12 | 155 | 28.4 | 2.37 | 7.7 | 251 |
| 11 | AVHT-109(GCH-5) | 2007-08 | 336 | 54.5 | 3.55 | 10.5 | 438 |
|  | GCH-5 | 2009-10 | 269 | 42.3 | 2.98 | 8.9 | 312 |
|  | GCH-5 | 2010-11 | 145 | 23.5 | 0.86 | 7.6 | 185 |
| check | AVHT-112(48-1) | 2007-08 | 314 | 54.4 | 2.50 | 10.7 | 399 |
|  | 48-1 | 2008-09 | 184 | 26.4 | 1.64 | 8.6 | 144 |
|  | 48-1 | 2009-10 | 350 | 58.1 | 5.45 | 10.5 | 452 |
|  | 48-1 | 2010-11 | 572 | 95.8 | 3.88 | 12.7 | 817 |
|  | 48-1 | 2011-12 | 107 | 18.7 | 1.37 | 6.3 | 186 |
| **Poor root genotypes used as checks for field screening** | | | | | | | |
| 1 | RG 1520 | 2009-10 | 59 | 8.0 | 0.49 | 4.9 | 111 |
| 2 | RG 1628 | 2009-10 | 63 | 11.5 | 0.29 | 6.8 | 83 |
| 3 | RG 2068 | 2007-08 | 94 | 15.2 | 1.42 | 6.7 | 101 |

**2. Study of root growth under control and stress conditions (root structure and field study) (2011-12):**

Two genotypes, one with good root growth (RG111) and one with poor root growth (RG1520) were studied in root structure for root and shoot growth by imposing stress from 30-90DAS during late *rabi* (2011-12). Root length reduction was not much due to stress. But root volume, dry weight and shoot growth reduced with stress, but the % reduction was less in poor root genotype (RG1520) compared to good root genotype (RG111) (Table 2).

Table 2: Root and shoot growth of poor and good root genotypes in control and stress treatments

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Growth character | **RG 111** | | **RG1520** | | **% reduction** | |
| **Control** | **Stress** | **Control** | **Stress** | **RG111** | **RG1520** |
| Root length (cm) | 154 | 158 | 155 | 149 | -4.0 | 3.9 |
| Root vol.(ml) | 88 | 33 | 75 | 34 | 63 | 54 |
| Root dry wt.(g/pl.) | 12.2 | 5.6 | 10.1 | 7.2 | 54 | 28 |
| Stem girth(cm) | 6.1 | 4.6 | 5.3 | 4.6 | 24 | 14 |
| LAI | 2.05 | 0.81 | 1.84 | 0.74 | 61 | 60 |
| TDM (g/pl.) | 128 | 46 | 125 | 56 | 64 | 55 |
| RWC (%) | 93.4 | 90.6 | 94.4 | 91.9 | 2.7 | 2.5 |
| Proline (µ mole/g FW) | 590 | 595 | 680 | 354 | -0.85 | 48 |
| Bloom content (μg/cm2) | 65 | 85 | 56 | 80 | -30.8 | -43 |
| Total seed yield (g/pl.) | 188 | 105 | 121 | 85 | 56 | 70 |
| DSI | 1.14 | | 1.43 | |  |  |

With drought stress in field, the seed yield reduction was more in poor root genotype (RG 1520) and also recorded high drought susceptibility index (DSI).

**3.Confirmation of drought tolerance of castor lines with better root traits in field conditions:**

**(2009-10 to 2014-15)**

Out of 60 germplasm and 11 breeding lines selected (2006-2012) for good root traits, 36 germplasm lines were screened for their drought tolerance in field along with poor root genotypes and a variety (48-1) and hybrid (DCH-519) as checks during late *rabi,* from 2009-10 to 2014-15. Water stress was imposed from 30-90 DAS and data on important growth and biochemical parameters were recorded before relieving stress and yield components and yield were recorded to identify genotypes with better drought tolerance even in field. During different years, data on 10 genotypes out of 36 screened could not be recorded due to severe wilt incidence. Two years data of 22 genotypes and three years data of 4 genotypes was recorded.

In general, water stress resulted in severe growth reduction in terms of reduced plant height, leaf number, stem girth, branches and dry matter. Growth of primaries and secondaries was affected and there was significant reduction in effective spike length, capsule number and seed yield. After relieving stress, tolerant genotypes tried to compensate the growth reduction with production of more no. of tertiaries and quarternaries. Based on the data, a total of 12 best genotypes with good root growth and drought tolerance were recorded. The data on % reduction in seed yield and drought susceptibility index of the selected genotypes is presented in Table 3.

Table 3. Total seed yield, seed yield reduction (%) and drought susceptibility index (DSI) of the selected genotypes

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **S. No.** | **Genotype** | **Year** | **Total seed yield(g/plant)** | | **% reduction** | **DSI** |
| **Control** | **Stress** |
| 1 | RG 27 | 2013-14 | 164 | 120 | 27.0 | 0.82 |
|  |  | 2014-15 | 109 | 92 | 16.0 | 1.00 |
| 2 | RG 72 | 00-01 | 30.2 | 26 | 13.9 | 0.33 |
|  |  | 14-15 | 116 | 102 | 12.6 | 0.79 |
| 3 | RG 82 | 2010-11 | 98.0 | 70.5 | 28.0 | 0.77 |
|  |  | 2011-12 | 152 | 78 | 48.8 | 1.4 |
| 4 | RG 89 | 2002-03 | 43 | 49 | -15 | -0.56 |
|  |  | 2014-15 | 72.5 | 70.2 | 2.3 | 0.20 |
| 5 | RG111 | 2002-03 | 34.5 | 34.3 | 0.6 | 0.02 |
|  |  | 2011-12 | 141.4 | 109.3 | 22.7 | 0.65 |
| 6 | RG 298 | 2002-03 | 49 | 52 | -5.9 | -0.23 |
|  |  | 2013-14 | 128 | 86 | 32 | 0.96 |
| 7 | RG 1437 | 2010-11 | 80.5 | 60.2 | 18.0 | 0.50 |
|  |  | 2011-12 | 124.1 | 64.6 | 47.9 | 1.37 |
| 8 | RG 1494 | 2010-11 | 36.7 | 40.5 | -10.2 | -0.28 |
|  |  | 2011-12 | 95.4 | 79.0 | 17.1 | 0.49 |
| 9 | RG 1826 | 2014-15 | 114.8 | 114.6 | 0.2 | 0.01 |
| 10 | RG1941 | 2010-11 | 63 | 49 | 22.2 | 0.61 |
|  |  | 2011-12 | 72.4 | 41.12 | 43.2 | 1.24 |
| 11 | RG 2139 | 2010-11 | 66.1 | 56.7 | 14.2 | 0.39 |
|  |  | 2011-12 | 106.1 | 84.4 | 20.5 | 0.59 |
| 12 | RG 2797 | 2010-11 | 118.6 | 95.3 | 19.6 | 0.54 |
|  |  | 2011-12 | 144.9 | 62.1 | 57.1 | 1.64 |
| **Poor root checks** | | | | | | |
| 1 | RG 1520 | 2011-12 | 84.6 | 25.3 | 70.1 | 1.43 |
| 2 | RG 1628 | 2010-11 | 92 | 54.7 | 40.5 | 1.12 |
|  |  | 2011-12 | 112.6 | 24.4 | 78.3 | 1.60 |
| 3 | RG 2068 | 2010-11 | 96.7 | 66.6 | 31.1 | 0.86 |
|  |  | 2011-12 | 94.0 | 29.5 | 68.6 | 1.40 |

**4. Screening identified germplasm lines with drought tolerance under *kharif* condition: (2014-15)**

Six germplasm lines with known drought tolerance in previous experiments along with checks (48-1, DCH-519) were grown under rainfed conditions (no irrigation was given) during *kharif*, 2014 with four replications in RBD. All genotypes matured by 150 days. There were not many tertiaries produced. Crop was lanky due to continuous rain fall and more cloudy days during early stages of crop growth.

Table 4: Seed yield of different spike orders, TDM and HI of different genotypes

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Genotypes** | **Seed yield (g/plant)** | | | | **TDM**  **at harvest (g/pl.)** | **HI (%)** |
| **Primary** | **Secondary** | **Tertiary** | **Total** |
| DCH-519 | 42.2 | 45.5 | 0 | 87.7 | 268.6 | 32.6 |
| RG 111 | 16.3 | 47.2 | 0 | 63.5 | 195.3 | 32.3 |
| RG 298 | 23.2 | 51.8 | 40.9 | 115.9 | 256.6 | 45.1 |
| RG 1437 | 23.2 | 45.2 | 0 | 68.4 | 297.5 | 22.9 |
| RG 1494 | 31.8 | 44.6 | 0 | 76.4 | 233.3 | 32.7 |
| RG 1826 | 24.8 | 35.0 | 51.8 | 111.6 | 241.9 | 46.1 |
| RG 2797 | 33.7 | 0.0 | 0 | 33.7 | 312.1 | 10.9 |
| 48-1 | 29.3 | 66.5 | 0 | 95.8 | 302.4 | 31.9 |
| **Mean** | 28.0 | 42 |  | 81.58 | 263.5 | 31.9 |
| **SEm ±** | 3.2 | 4.2 |  | 4.45 | 12.23 | 1.39 |
| **CD p: 0.05** | 9.6 | 12.8 |  | 13.48 | 37.1 | 4.23 |
| **CV(%)** | 19.6 | 17.4 |  | 9.44 | 8.04 | 7.58 |

Primary seed yield was significantly higher in RG 2797, RG 1494 which was on par with check DCH-519 (Table 4). Though there were secondary branches produced, no seed yield of secondaries in RG 2797. Secondary seed yield was more in RG 298 after the check variety 48-1. Tertiary seed yield was recorded only in RG 298 and RG 1826 and total seed yield was also significantly higher in these two genotypes. Total dry matter at harvest was more in RG 2797, RG 1437 but seed yield and harvest index were significantly higher in RG 298 and RG 1826 which shows better performance of these genotypes in rainfed conditions though all other genotypes also showed drought tolerance in field during previous years of experimentation by withholding irrigation from 30 – 90 DAS. Potassium iodide (KI) was sprayed @ 0.2% during tertiary spike seed filling to induce desiccation to identify genotypes with terminal drought tolerance. However, crop desiccation could not be induced with 0.2% KI spray.

**5. Seedling tolerance of castor genotypes with desirable root traits for drought, temperature and salinity: (2012-13 to 2014-15)**

Selected germplasm with good root traits were screened in lab for germination with Poly Ethylene Glycol (PEG) induced drought stress. Seeds of different germplasm lines were sown in petriplates with PEG solutions of different concentrations that can induce 0, -2, -4, -6, -8 and -1.0 mega pascals (MPa) of drought stress. Data on germination percent and days to germination were recorded. Castor could germinate upto -6 MPa only. A total of 42 germplasm were screened and 10 were selected with drought tolerance during germination with >75% germination at -2 MPa osmotic potential and showed survival even at -4 MPa (Table 5). RG 111 recorded 47% and RG 72 recorded 50% germination even at -6 MPa.

Temperature Induction Response technique (TIR) was standardized for castor (Lakshmamma and Lakshmi Prayaga, 2006) and Optimum lethal and induction temperatures were identified as 48ºC for 2 hours; 35ºCfor 2 h followed by 40ºC for 2 h and 45ºC for one hour respectively. 44 genotypes selected with good root and WUE traits were screened for temperature tolerance at seedling level using this technique. 13 best genotypes with >75% seedling survival with induction temperature and >40% survival even at lethal temperature were selected (Table 5). RG 72, RG 1826, RG 2048 and RG 2439 showed >90% seedling survival at induction and >80% survival even at lethal temperature.

During 2013-14, 6 genotypes were screened for salinity tolerance during germination with different concentrations of NaCl viz; 0, 50, 100, 150, 200 and 250 mM. 3 germplasm lines with >70% germination in 100mM NaCl were selected (Table 5).

Table 5. Selected germplasm lines with drought, temperature and salinity tolerance during germination and seedling growth.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **S.No.** | **Year of study** | **Tolerance to** | | | | | |
| **Drought**  **(PEG induced)** | | **Temperature**  **(TIR technique)** | | **Salinity**  **(NaCl induced)** | |
|  |  | No. screened | No. selected | No. screened | No. selected | No. screened | No. selected |
|  | 2012-13 | 13 | 4 | 19 | 5 | - | - |
|  | 2013-14 | 20 | 4 | 15 | 4 | 6 | 3 |
|  | 2014-15 | 9 | 2 | 10 | 4 | - | - |
|  | Total | **42** | **10** | **44** | **13** | **6** | **3** |
|  |  | **Selected genotypes** | | **Selected genotypes** | | **Selected genotypes** | |
|  |  | RG72 | RG289 | RG72 | RG1661 | RG289 |  |
|  |  | RG82 | RG298 | RG89 | RG1826 | RG941 |  |
|  |  | RG89 | RG1494 | RG111 | RG1941 | RG2149 |  |
|  |  | RG111 | RG2048 | RG211 | RG2048 |  |  |
|  |  | RG248 | RG2139 | RG941 | RG2094 |  |  |
|  |  |  |  | RG1618 | RG2153 |  |  |
|  |  |  |  |  | RG2439 |  |  |

Out of 12 best genotypes with good root growth and drought tolerance in field, 9 were screened with PEG induced stress in lab and 7 (RG 72, RG 82, RG 89, RG 111, RG 298, RG 1494, RG 2139) were selected for drought tolerance during seed germination also. All the 5 genotypes that were screened with TIR (RG 72, RG 89, RG 111, RG 1826 and RG 1941) also showed seedling tolerance to temperature. Only 4 germplasm lines (RG 89, RG 1437, RG 1826 and RG 2139) were screened for salinity tolerance so far and none showed tolerance to salinity during germination. The screening of remaining lines for PEG, TIR, salinity stress will continue for these lines in new germplasm project. So far, the best lines with good root growth, field tolerance to drought, seedling tolerance to drought and temperature include: RG 72, RG 89 and RG 111.Among these, RG 72 was already registered for its drought tolerance.

**6. Effect of Trichoderma on drought stress alleviation in castor: (2012-13)**

An experiment was conducted using ten trichoderma isolates as seed treatment @10g per kg seed in DCH-519 castor hybrid during *rabi/summer*, 2012-13. Drought stress was imposed by withholding irrigation from 30-90DAS along with irrigated and untreated controls as checks. There was growth reduction due to water stress (reduction in plant height, leaf no., stem girth, branch production and TDM). In stressed plots, trichoderma seed treatment improved the crop growth and dry matter production compared to untreated control. But in irrigated plots, the effect of trichoderma is not significant. SCMR increased in drought stressed plots due to decreased leaf area and increased specific leaf weight.

Table 6: Seed yield of different order branches and total seed yield (g/plant)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S.No.** | **Trichoderma treatments** | **Seed yield of different order branches (g/pl.)** | | | | **total seed yield (g/pl.)** | **TDM at harvest (g/pl.)** | **HI (%)** |
| **Primary** | **Secondary** | **Tertiary** | **Quarternary** |
| **Control (irrigated)** | |  |  |  |  |  |  |  |
| 1 | TV 2 | 75.3 | 48.3 | 22.0 | 45.2 | 190.7 | 559.2 | 34.1 |
| 2 | TV 5 | 59.1 | 53.9 | 33.0 | 51.2 | 197.2 | 588.3 | 33.5 |
| 3 | TA 2 | 59.8 | 53.7 | 36.6 | 44.6 | 194.7 | 611.9 | 31.8 |
| 4 | T 79 | 70.5 | 52.1 | 30.2 | 39.4 | 192.1 | 590.3 | 32.5 |
| 5 | KA 8D | 66.3 | 61.0 | 57.0 | 57.8 | 242.1 | 641.0 | 37.8 |
| 6 | T 673 | 72.6 | 54.2 | 24.7 | 60.2 | 211.6 | 624.0 | 33.9 |
| 7 | T 7316 | 58.7 | 50.8 | 20.6 | 38.4 | 168.6 | 547.9 | 30.8 |
| 8 | Th 4d | 49.4 | 51.1 | 24.7 | 29.0 | 154.3 | 541.4 | 28.5 |
| 9 | GJ 11A | 66.0 | 54.9 | 41.2 | 38.2 | 200.3 | 543.8 | 36.8 |
| 10 | TN 13 | 61.8 | 51.0 | 41.0 | 12.4 | 166.2 | 512.4 | 32.4 |
| **11** | **untreated C** | **70.0** | **39.4** | **21.3** | **31.2** | **161.8** | **493.7** | **32.8** |
|  | ***average*** | ***64.5*** | ***51.8*** | ***32.0*** | ***40.7*** | ***189.0*** | ***568.5*** | ***33.2*** |
| **Drought stress** | |  |  |  |  |  |  |  |
| 12 | TV 2 | 46.1 | 51.1 | 53.2 | 32.3 | 182.7 | 468.9 | 39.0 |
| 13 | TV 5 | 39.5 | 41.8 | 66.7 | 38.0 | 186.1 | 595.5 | 31.2 |
| 14 | TA 2 | 31.3 | 49.6 | 75.3 | 32.3 | 188.4 | 572.1 | 32.9 |
| 15 | T 79 | 25.0 | 35.7 | 62.4 | 39.5 | 162.6 | 598.3 | 27.2 |
| 16 | KA 8D | 30.5 | 44.8 | 53.0 | 33.8 | 162.1 | 527.3 | 30.7 |
| 17 | T 673 | 42.8 | 55.6 | 69.0 | 36.4 | 203.8 | 552.2 | 36.9 |
| 18 | T 7316 | 37.5 | 39.1 | 71.8 | 43.4 | 191.8 | 596.2 | 32.2 |
| 19 | Th 4d | 44.8 | 55.1 | 58.0 | 13.6 | 171.4 | 622.6 | 27.5 |
| 20 | GJ 11A | 27.7 | 38.2 | 32.3 | 18.7 | 117.0 | 472.9 | 24.7 |
| 21 | TN 13 | 35.0 | 50.7 | 48.8 | 34.0 | 168.6 | 604.7 | 27.9 |
| **22** | **untreated S** | **26.3** | **22.5** | **17.8** | **15.3** | **81.9** | **277.4** | **29.5** |
|  | ***average*** | ***35.1*** | ***43.3*** | ***55.3*** | ***30.5*** | ***163.4*** | ***535.3*** | ***30.1*** |

In general, with water stress from 30-90DAS, there was reduction in seed yield of primaries, secondaries and total seed yield. Trichoderma seed treatment improved the seed yield of primaries, secondaries, tertiaries, quarternaries and thereby total seed yield by increasing spike number, effective spike length, capsule number and test weight in stressed plots. However, there was variation in growth due to slope of the field which effected the growth of untreated plots. Hence, the effect of trichoderma strains on drought stress alleviation needs confirmation. T673 and T7316 isolates recorded more total seed yield followed by TV2, TV5 and TA2 in stressed plots. Further studies on effect of trichoderma on drought stress alleviation were being carried out in AMAAS project.

**7. Screening cultivated varieties and hybrids of castor for temperature tolerance: (2012-13 to 2013-14)**

Ten hybrids and four varieties were sown for two years at four dates of sowing during November, to January, to identify temperature tolerant genotypes. During 2012-13, with delayed sowings from November 16th to January 18th (60 days), crop growth hastened by reducing the days to flowering of different spike orders by 9-20 days and crop duration by 50 days (Table 7).

Table 7: Days to flowering and harvesting at different dates of sowing.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | 16/11/2012 | 7/12/2012 | 26/12/2012 | 18/1/2013 | Difference |
| Days to  50% flowering | Of Primary | 54 | 52 | 50 | 45 | -9 |
| Of secondaries | 87 | 70 | 68 | 67 | -20 |
| Of tertiaries | 105 | 91 | 91 | 89 | -16 |
| Days to  harvesting | Of Primary | 131 | 115 | 106 | 99 | -32 |
| Of secondaries | 142 | 125 | 124 | 113 | -29 |
| Of tertiaries | 149 | 164 | 152 | 153 | +4 |
| Final harvesting | 218 | 195 | 181 | 168 | -50 |

On average, there was increase of 0.7oC in maximum temperature, 2.1oC in minimum temperature and 4% reduction in relative humidity from 1st to 4th sowing. Evaporation increased by 0.7mm (Table 8).

Seed yield of primary and secondary orders reduced with delayed sowings, but crop tried to compensate by producing more seed yield of late order branches (Table 9). Genotypes with less (<10%) reduction in total seed yield with delayed sowings include Gauch-1, GCH-2, GCH-5 and DCH-519. Data of 2013-14 is not presented as there was severe wilt infestation of few genotypes.

Table 8. Weather data for four sowings.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Difference from 1st – 4th sowing** | Days | **Temp. (0C)** | | **Humidity (%)** | | **Sunshine**  **(hrs)** | **Rain**  **(mm)** | **Evapora-**  **tion (mm)** |
| **Max.** | **Min.** | **I** | **II** |
| Primary flowering | -9 | +1.1 | +0.4 | +1.2 | +4.6 | +1.0 | +0.4 | +2.3 |
| Secondary flowering | -20 | +1.9 | +2.1 | +1.3 | -1.6 | +0.3 | +0.3 | +1.9 |
| Tertiary flowering | -16 | +3.3 | +3.7 | -0.2 | -6.6 | +0.3 | +0.1 | +2.4 |
| **Sowing to harvest** | **-50** | **+0.7** | **+2.1** | **-1.8** | **-4.0** | **-0.9** | **+0.3** | **+0.7** |
| **Average for different sowings for crop duration** | **Duration** |  |  |  |  |  |  |  |
| 1st sowing (16/11/2012) | 218 | 33.6 | 19.4 | 91.5 | 78.1 | 8.1 | 0.9 | 6.4 |
| 2nd sowing (7/12/2012) | 195 | 34.3 | 20.0 | 90.7 | 77.1 | 8.1 | 1.1 | 6.8 |
| 3rd sowing (26/12/2012) | 179 | 34.1 | 20.0 | 91.2 | 76.5 | 8.0 | 1.1 | 6.8 |
| 4th sowing (18/1/2013) | 168 | 34.3 | 21.5 | 86.7 | 74.1 | 7.2 | 1.2 | 7.1 |

Table 9. Average seed yield of different order branches at different dates of sowing.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Avearge Seed yield/plant (g/pl.)** | **Sowing dates** | | | | **Difference from 1st – 4th sowing (g/plant)** |
| **16/11/12** | **7/12/12** | **26/12/12** | **18/1/13** |
| Of Primary | 60.5 | 55.3 | 55.4 | 39.5 | -21.0 |
| Of secondaries | 51.4 | 43.2 | 46.6 | 36.9 | -14.5 |
| Of tertiaries | 33.9 | 46.9 | 30.7 | 50.0 | +16.1 |
| Of quarternaries | 36.7 | 43.3 | 44.7 | 37.7 | +1.0 |
| **Total seed yield** | **180.8** | **188.8** | **178.1** | **164.1** | **-16.7** |

**Objective 2:** **To study source-sink relationships**

Field investigation was carried out for 2 years during 2005-07 to determine yield loss to different levels of defoliation (25%, 50%, 75% and 100%) at primary, secondary and tertiary spike initiation stages in castor (cv. DCS 9). Defoliation at secondary spike initiation stage was found to be the most sensitive stage which reduced seed yield of all order branches. Defoliation at any stage beyond 25% significantly reduced seed yield in castor. Keeping this data as base, the objective on source sink relationships was continued in new project.

1. **Yield reduction with defoliation of young leaves in castor: (2009-10)**

Yield reduction from defoliation of young leaves in castor (48-1) was studied during *kharif* 2009-10 by imposing defoliation @ 0, 25, and 50% from top at spike initiation stage on primary, secondary and tertiary branches separately and in combinations. Experimental design was randomized block with three replications and five rows per replication. Defoliation was done from top and 25 or 50% of the leaves of that order, on each branch were removed at a particular stage. Removed leaf number and area were quantified (Table: 10). Data on growth, dry matter, yield components and yield of different order branches was recorded.

Table 10: Actual percent defoliation imposed

|  |  |  |
| --- | --- | --- |
| **% defoliation** | **Removed leaf area (%)** | **Average % defoliation** |
| 25% on primary | 9-23 | 16 |
| 50% on primary | 23-31 | 27 |
| 25% on secondary | 38-44 | 41 |
| 50% on secondary | 48-73 | 61 |
| 25% on tertiary | 38-47 | 43 |
| 50% on tertiary | 47-59 | 53 |

Table 11: Seed yield of different spike orders

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **S.No.** | **Treatment** | **Primary** | **Secondary** | **Tertiary** | **Quarternary** | **Pentenary** | **Total Seed**  **yield (g/plant)** |
| 1 | 25%P | 22.2 | 19.1 | 70.7 | 39.5 | 34.5 | 185.9 |
| 2 | 50%P | 21.3 | 23.0 | 66.2 | 30.9 | 35.1 | 176.5 |
| 3 | 25%P+S | 22.9 | 16.2 | 64.3 | 38.5 | 35.5 | 177.4 |
| 4 | 50%P+S | 20.3 | 15.1 | 59.7 | 34.0 | 46.8 | 176.0 |
| 5 | 25%P+T | 23.5 | 21.5 | 43.2 | 32.5 | 40.6 | 161.4 |
| 6 | 50%P+T | 18.8 | 22.8 | 34.2 | 34.7 | 36.8 | 147.3 |
| 7 | 25%P+S+T | 24.7 | 19.9 | 45.2 | 31.1 | 36.5 | 157.3 |
| 8 | 50%P+S+T | 21.8 | 17.5 | 37.0 | 33.9 | 34.5 | 144.7 |
| 9 | 25%S | 29.2 | 19.7 | 60.6 | 31.7 | 47.2 | 188.4 |
| 10 | 50%S | 32.3 | 17.6 | 64.5 | 33.8 | 37.3 | 185.5 |
| 11 | 25%S+T | 26.8 | 17.4 | 41.7 | 33.9 | 45.3 | 165.1 |
| 12 | 50%S+T | 23.9 | 20.7 | 34.7 | 33.9 | 45.5 | 158.8 |
| 13 | 25%T | 24.8 | 24.0 | 46.5 | 31.7 | 39.9 | 166.9 |
| 14 | 50%T | 23.7 | 24.2 | 34.1 | 29.9 | 39.3 | 151.2 |
| 15 | control | 27.8 | 19.6 | 86.3 | 28.9 | 41.0 | 203.6 |
|  | Mean | 24.3 | 19.9 | 52.6 | 33.3 | 39.7 | **169.7** |
|  | SEm± | 2.02 | 2.03 | 4.2 | 2.5 | 3.31 | 6.35 |
|  | CD(0.05) | 5.85 | NS | 12.1 | NS | NS | 18.42 |
|  | CV(%) | 14.6 | 17.5 | 13.7 | 13.2 | 14.4 | 6.49 |

Primary seed yield reduced with 50% defoliation from top on primary either alone or in combination with other defoliation stages (Table: 11). Even with 25% defoliation the reduction was significant when defoliated on all order branches. Treatmental differences for secondary seed yield were not significant with defoliation as the growth of secondaries was affected due to stress followed by continuous, heavy rains from 40 to 85 days after sowing. Tertiary seed yield decreased significantly with defoliation on any order. In general, higher order branches compensate when defoliation was done on lower order branches, but as secondary growth and yield was affected due to erratic rain fall during that stage, even with defoliation on primary, tertiary seed yield was affected. With increase in % defoliation at any stage, there was significant reduction in tertiary seed yield. Plants tried to compensate by producing quarternaries and pentenaries.

Total seed yield reduced with defoliation, but the reduction was not significant for 25% defoliation on primary (actual defoliation was 12% only) and 25, 50% defoliation only on secondaries. Overall, the seed yield reduction was 13% in primary, 42% in tertiary, and 18% in total (Table: 12).

Table 12: TDM, Total seed yield and % reduction in seed yield with different defoliation treatments

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Sl.No. | Treatment | TDM (g/pl.) | Total Seed  yield (g/plant) | % reduction in seed yield |
| 1 | 25%P | 483 | 185.9 | 9 |
| 2 | 50%P | 446 | 176.5 | 13 |
| 3 | 25%P+S | 490 | 177.4 | 13 |
| 4 | 50%P+S | 468 | 176.0 | 14 |
| 5 | 25%P+T | 429 | 161.4 | 21 |
| 6 | 50%P+T | 386 | 147.3 | 28 |
| 7 | 25%P+S+T | 382 | 157.3 | 23 |
| 8 | 50%P+S+T | 363 | 144.7 | 29 |
| 9 | 25%S | 484 | 188.4 | 8 |
| 10 | 50%S | 483 | 185.5 | 9 |
| 11 | 25%S+T | 442 | 165.1 | 19 |
| 12 | 50%S+T | 457 | 158.8 | 22 |
| 13 | 25%T | 427 | 166.9 | 18 |
| 14 | 50%T | 369 | 151.2 | 26 |
| 15 | control | 538 | 203.6 |  |
|  | **Mean** | **443** | **169.7** | **18** |
|  | SEm± | 14.3 | 6.35 |  |
|  | CD(0.05) | 41.3 | 18.42 |  |
|  | CV(%) | 5.6 | 6.49 |  |

Thus, leaf removal from top at any stage and even with 25% showed significant reduction in total seed yield. Loss in the early stages can be compensated to some extent with growth in higher order branches. Yield reduction was more with defoliation on all order branches.

**2. Yield compensation in castor with nipping of different order spikes: (2012-13)**

Effect of nipping of different order spikes at spike initiation or at full expansion on yield compensation in castor was studied during *kharif*, 2012 in DCH-519 hybrid in RBD with three replications. Data on seed yield of different order branches, total seed yield, TDM and HI were presented (Table 13).

Differences in stem weight and TDM at harvest were not significant with nipping of primary, secondary, tertiary order spikes at spike initiation or at full expansion. Nipping of primary spike at any stage increased seed yield of secondaries by increasing effective spike length and capsule number but reduced tertiary seed yield. Seed yield of 4th order was on par in all treatments. Total seed yield was on par with control in nipping of any one order spikes at any stage which shows the extent of compensation in castor.

Table 13: Seed yield (g/plant) of different order branches with nipping of spikes

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Seed Yield (g/plant)** | | | | | **Stem dry weight (g/pl.)** | **TDM**  **(g/pl.)** | **HI (%)** |
|  | **Treatments** | **Primary** | **Secondary** | **Tertiary** | **Quarternary** | **Total**  **seed**  **Yield** |
| 1 | Keeping all spikes (control) | 52.7 | 48.9 | 67.3 | 88.0 | 257.0 | 211.2 | 649.1 | 40.1 |
|  | **Nipping of spikes** |  |  |  |  |  |  |  |  |
| 2 | Primary at initiation(SI) | 0.0 | 75.0 | 50.6 | 91.3 | 217.0 | 258.5 | 668.1 | 32.5 |
| 3 | Primary at full expansion(FE) | 0.0 | 69.7 | 52.9 | 100.2 | 222.7 | 220.8 | 586.9 | 37.9 |
| 4 | Secondary at initiation | 57.3 | 0.0 | 58.7 | 93.0 | 209.0 | 261.6 | 630.7 | 33.2 |
| 5 | Secondary at full expansion | 52.2 | 0.0 | 71.6 | 85.1 | 208.9 | 237 | 599.8 | 34.8 |
| 6 | Tertiary at initiation | 54.8 | 62.2 | 0.0 | 103.1 | 220.0 | 246 | 610.9 | 36.0 |
| 7 | Tertiary at full expansion | 53.1 | 55.2 | 0.0 | 91.7 | 199.9 | 229.5 | 553.7 | 36.8 |
|  | **mean** | **38.6** | **44.4** | **43.0** | **93.2** | **219.2** | **237.8** | **614.2** | **35.9** |
|  | **SEm** | **3.48** | **6.40** | **4.1** | **9.1** | **15.6** | **29.3** | **47.2** | **2.0** |
|  | **CD(0.05)** | **10.7** | **19.70** | **12.5** | **NS** | **NS** | **NS** | **NS** | **NS** |
|  | **CV(%)** | **15.6** | **25.0** | **16.4** | **16.9** | **12.3** | **21.3** | **13.3** | **9.5** |

**3. Leaf fall quantification in castor: (2013-14 to 2014-15)**

An experiment was conducted during 2013-15 for two years to devise suitable methodology for leaf fall quantification while working out plant dry matter. During 2013-14, fallen leaf of 34 breeding lines was collected at 10 days interval from 35 DAS. In *kharif*, 2014, 3 genotypes with differences in LAI (1-5), RG 2149, RG2058, RG 387 along with variety 48-1, hybrid DCH-519 checks were sown in 3 replications with 5 rows each. In all genotypes, each leaf on 10 plants was tagged by using different colour ribbons. Data on fallen leaf number, leaf dry weight, seed yield of different order branches and TDM at harvest were recorded. Fallen leaf weight percent in total dry matter ranged from 15 – 27 with a mean of 20%. Based on 2 years data, equation for estimation of TDM and HI with senescing/fallen leaf weight was derived using linear method with TDM, HI including fallen leaf as dependent variables and TDM, HI without fallen leaf as independent variables (K Alivelu).

TDM with fallen leaf weight = 1.229 X TDM without fallen leaf weight

HI with fallen leaf weight = 0.797 X HI without fallen leaf weight

Validation of regression model shows that the correlation between observed and selected values by the use of this equation was very high.

**4. Selection of castor parents with high harvest index: (2014-15)**

During 2013-14,Promising parents for high harvest index (48-1, DCS 89, DCS 109, DCS 119, k12-86-2, k12-91-2, k12-98-3, k12-1555-1, M 571, DCH-1566) were identified. Selected three breeding lines along with two checks were sown in four replications during 2014-15. Seedling vigor was more in K12-86-2 followed by K12-98-3. Primary, tertiary, total seed yield, TDM and HI did not differ among the breeding lines except secondary seed yield which was significantly higher in K12-86-2 and K12-98-3 (Table:14).

Table 14: TDM, seed yield and HI of breeding lines

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Genotype** | **Seedling**  **vigour**  **(g/pl.)** | **Seed yield (g/plant)** | | | | **TDM at harvest (g/pl.)** | **HI (%)** |
| **Primary** | **Secondary** | **Tertiary** | **Total** |
| DCH519 | 0.52 | 35.6 | 35.3 | 27.2 | 98.1 | 523 | 18.9 |
| K12-86-2 | 1.17 | 23.5 | 69.2 | 53.6 | 146.3 | 443 | 33.7 |
| K12-91-2 | 0.69 | 21.2 | 59.6 | 51.1 | 131.9 | 475 | 27.7 |
| K12-98-3 | 0.88 | 29.8 | 72.0 | 45.6 | 147.4 | 487 | 30.4 |
| 48-1 | 0.74 | 32.5 | 80.2 | 60.9 | 173.6 | 557 | 31.3 |
| Mean | 0.80 | 28.5 | 63.2 | 47.7 | 139.4 | 497 | 28.4 |
| SEm ± | 0.047 | 5.76 | 5.94 | 3.41 | 8.68 | 19.65 | 2.51 |
| CD p:0.05 | 0.15 | NS | 19.4 | 11.1 | 28.3 | 64.08 | 8.19 |
| CV(%) | 10.10 | 35.0 | 16.3 | 12.4 | 10.8 | 6.9 | 15.31 |

None of these parental lines out yielded check variety 48-1. K12-86-2 recorded 33.7% HI followed by 48-1 (31.3) and K12-98-3 (30.4%).

**ANNEXURE -VI**

**INDIAN COUNCIL OF AGRICULTURAL RESEARCH**

**CHECKLIST FOR SUBMISSION OF FINAL RESEARCH PROJECT REPORT (RPP-III)**

**(For Guidelines Refer ANNEXURE – XI (F))**

1. Institute Project Code: 104-7
2. Investigators as approved in RPP-I, If any change attach IRC proceedings:

|  |  |  |
| --- | --- | --- |
| Principal Investigator | CC-PI | Co-PI |
| P. Lakshmamma |  | Lakshmi Prayaga |

1. Any change in objectives and activities Yes/No: No

(If yes, attach IRC proceedings)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Date of Start & Date of Completion (Actual). If any extension granted enclose IRC proceedings | | 2009 -2015 |
|  | Whether all objectives met | | Yes |
|  | All activities completed | | Yes |
|  | Salient achievements/major recommendations included | | Yes |
|  | Annual Progress Reports (RPP-II) submitted | 2009-10 | Yes |
| 2010-11 | Yes |
| 2011-12 | Yes |
| 2012-13 | Yes |
| 2013-14 | Yes |
|  | Reprint of each of publication attached | | Yes |
|  | Action for further pursuit of obtained results indicated | | Yes |
|  | Report presented in Divisional seminar (enclose proceedings & action taken report) | | Yes.  Discussed in PRE IRC and IRC meetings |
|  | Report presented in Institute seminar (enclose proceedings & action taken report) | |
|  | IRC number in which the project was adopted | | 104-7 |
|  | Any other Information | |  |

1. Signature:
2. Signature of PI, CC-PI(s), all Co-PIs

(P. Lakshmamma) (Lakshmi Prayaga)

(Project Leader) (Co-PI)

1. Signature of HOD/PD/I/c.

(I Y L N Murthy) (K.S. Varaprasad)

(Head, Crop Production) (Director, ICAR-IIOR)

**ANNEXURE - VIII**

**INDIAN COUNCIL OF AGRICULTURAL RESEARCH**

**(For Guidelines Refer ANNEXURE – XI(H))**

**PROFORMA FOR RESEARCH PERFORMANCE EVALUATION OF INDIVIDUAL SCIENTIST**

1. Institute Project Code \*: 104-7
2. Evaluation by PI on the contribution of the team in the project including self

|  |  |  |  |
| --- | --- | --- | --- |
| S. No. | Name | Status in the project  (PI/CC-PI/Co-PI) | \*Rating in the scale of 1 to 10 |
| 1 | P.Lakshmamma |  | 9 |
| 2 | Lakshmi Prayaga |  | 9 |

1. Signature of PI

\* Individual scientists participating in the project would be assessed for their performance through an appraisal system in a scale of 1 to 10 for each of the following attributes:

|  |  |  |
| --- | --- | --- |
| **S. No.** | **Criteria** | **Marks** |
|  | Percentage of the assigned activity completed | **30** |
|  | Quality of the completed activity | **10** |
|  | Authenticity/reliability of the data generated | **10** |
|  | Enthusiasm and sincerity to work | **10** |
|  | Inferences made | **10** |
|  | Collaboration and cooperation demonstrated in performing the task at hand | **10** |
|  | Amenability to scientific/academic/laboratory discipline | **10** |
|  | Total Score | **90** |

**`ANNEXURE - IX**

**INDIAN COUNCIL OF AGRICULTURAL RESEARCH**

**(For Guidelines Refer ANNEXURE – XI(I))**

**PROFORMA FOR EVALUATION OF A RESEARCH PROJECT AFTER COMPLETION BY PI**

1. Institute Project Code
2. Evaluation research project after completion by PI

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **S.**  **No.** | **Criteria** | **Methodology** | | **Marks (output)** | **Self Evaluation by PI** |
| 1. | Achievements  Against approved and stipulated outputs under project | **Qualitative and quantitative assessment of objectives and stipulated outputs under the project will be carried out**   1. Activity Input /Projected Output/ Output Achieved 2. Extent to which standard design methodology, experimental designs, test procedures, analytical methods followed 3. Does the data justify the conclusions? 4. Innovativeness and creating of new knowledge 5. Additional outputs over those stipulated under the project 6. Creation of linkages for commercialization of technology developed under the project 7. Is scientific input commensurate to output (manpower, financial input and time duration)? | | **75**  35  10  05  10  05  05  05 | **65**  35  10  05  05  0  05  05 |
| 2. | Publication/ awards | Assessment will be done in respect of: Research papers; Reports/Manuals; Working and Concept Papers; Books/Book Chapters/Bulletins. Quality of publication (s) and Awards /Scientific recognitions received | | **10** | **08** |
| 3. | Additional facilities created | Facilities created in terms of laboratory. Research set-up, instrumentation, software, hardware etc. during the project. | | 05 | NA |
| 4. | Human Resource Development (Scientific and Technical) | Scientist trained in different areas | | 05 | NA |
| 5. | Revenue generated under the project/ avenues created for revenue generation | Resources and revenues generated | | 05 | NA |
| 6. | Product/ Process/Technology/ IPR/New Models/ Methods/Databases/ / Concept/ Tools/Technique /commercial value of the technology developed | Details to be provided on   1. Product 2. Process 3. Technology 4. IPR 5. Registration of the varieties 6. New Models 7. Methods 8. Tools 9. Databases 10. Concepts 11. Techniques | | **10** | **7**  (standardization of root structure for castor, selection of genotypes with good root, WUE traits, drought and temperature tolerance) |
| 7. | Quality of available documents of the project duly authenticated | Research Project Files, Data, Reports etc. | | **05** | **05** |
| **Total Marks** | | | | **115** | **85** |
| 8. | Timelines of execution of the project | Marks will be deducted if extension sought over the approved project duration beyond recorded and officially granted extension with recorded reasons | Marks  to be deducted |  | **-05** |
| Up to 5% | 01 |
| Up to 10% | 02 |
| Up to 30 % | 03 |
| Beyond 30 % | 05 |
| **Net Score: Score obtained to be counted out of 100 to compensate for activities not relevant to the project** | | | | **100** | **74** |

1. Signature of PI

**ANNEXURE - X**

**INDIAN COUNCIL OF AGRICULTURAL RESEARCH**

**(For Guidelines Refer ANNEXURE – XI (J))**

**PROFORMA FOR EVALUATION OF A RESEARCH PROJECT AFTER COMPLETION BY EVALUATION COMMITTEE**

1. Institute Project Code
2. Evaluation research project after completion by Evaluation Committee

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **S.**  **No.** | **Criteria** | | **Methodology** | **Marks (output)** | **Evaluation by Evaluation Committee** |
| 1. | Achievements  Against approved and stipulated outputs under project | | **Qualitative and quantitative assessment of objectives and stipulated outputs under the project will be carried out**   1. Activity Input /Projected Output/ Output Achieved 2. Extent to which standard design methodology, experimental designs, test procedures, analytical methods followed 3. Does the data justify the conclusions? 4. Innovativeness and creating of new knowledge 5. Additional outputs over those stipulated under the project 6. Creation of linkages for commercialization of technology developed under the project 7. Is scientific input commensurate to output (manpower, Financial input and time duration)? | **75**  35  10  05  10  05  05  05 |  |
| 2. | Publication/ awards | | Assessment will be done in respect of: Research papers; Reports/Manuals; Working and Concept Papers; Books/Book Chapters/Bulletins. Quality of publication (s) and Awards /Scientific recognitions received | **10** |  |
| 3. | Additional facilities created | | Facilities created in terms of laboratory. Research set-up, instrumentation, software, hardware etc. during the project. | **05** |  |
| 4. | Human Resource Development (Scientific and Technical) | | Scientist trained in different areas | **05** |  |
| 5. | Revenue generated under the project/ avenues created for revenue generation | | Resources and revenues generated | **05** |  |
| 6. | Product/ Process/Technology/ IPR/New Models/ Methods/Databases/ / Concept/ Tools/Technique /commercial value of the technology developed | | Details to be provided on   1. Product 2. Process 3. Technology 4. IPR 5. Registration of the varieties 6. New Models 7. Methods 8. Tools 9. Databases 10. Concepts 11. Techniques | **10** |  |
| 7. | Quality of available documents of the project duly authenticated | | Research Project Files, Data, Reports etc. | **05** |  |
| **Total Marks** | | | | **115** |  |
| 8. | Timelines of execution of the project | |  |  | | --- | --- | | Marks will be deducted if extension sought over the approved project duration beyond recorded and officially granted extension with recorded reasons | Marks to be deducted | | Up to 5% | 01 | | Up to 10% | 02 | | Up to 30 % | 03 | | Beyond 30 % | 05 | | |  |  |
| **Net Score: Score obtained to be counted out of 100 to compensate for activities not relevant to the project** | | | | **100** |  |

1. Signature of Evaluation Committee