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EVALUATION OF SUGARCANE (*Sacccharum officinarum* L.) MID-LATE CLONES UNDER WATERLOGGING CONDITIONS OF BIHAR (INDIA)

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ABSTRACT

Yield and juice quality of 16 sugarcane clones, procured from Sugarcane Research Institute, DRPCAU, Pusa, Samastipur, Bihar (India), was evaluated under waterlogging stress condition during 2016 to 2017. The trials were laid out in a randomized block design with three replications. The depth of water was 130 cm for 15 days of August. The experimental plot remained waterlogged during June-September 2016 varied from 30 to 90 cm. Three budded sets from upper half of the canes were used for planting. Planting was done following full agronomic and plant protection practices recommended for North Bihar (India) conditions. The result revealed high heritability coupled with high genetic advance, as per cent of means, for cane yield, leaf area index at 30 days after waterlogging, leaf area index before waterlogging, leaf area index at 60 days after waterlogging and sugar yield suggesting the preponderance of additive genetic effect in the determination of these traits. It also indicated that selection for these traits will be effective if desired improvement is to bring for cane and sugar yield under waterlogged condition. Ranking of clones based on selection index and three other criteria revealed that clone CoP2061 was the most suitable clone among the clones studied. The clone can directly be used as varieties for waterlogging tolerance and may be used in crossing programme as parents to develop waterlogging tolerant clone.

Key words: Rank correlation, selection indices, sugarcane, waterlogged tolerance

INTRODUCTION

Sugarcane production in many areas of the world suffers due to water-logging or flooding. Crop competition, increased pressure on land and various socio-economic factors have confined sugarcane cultivation to poorly drained, marginal land prone to seasonal inundation which affects productivity. A considerable area under sugarcane crop in several parts of India (Assam, Bihar, West Bengal, eastern Uttar Pradesh, coastal region of Andhra Pradesh, Tamil Nadu, Kerala and Karnataka) are exposed to stagnant water for two to three months during monsoon season. The short fall in yield potential is mainly due to various biotic and abiotic stresses in Bihar in which waterlogging is the main factor, because in Bihar about 35-40% sugarcane area remains waterlogged during monsoon season which coincides with the grand growth period of the crop. In waterlogged areas a negative correlation between excessive rainfall and productivity have been found (Salter and Schroeder, 2012; Garside *et al*., 2014). It is estimated that sugarcane lost 0.5 t ha^{-1} for every day the water-table was within 50 cm of soil surface (Rudd and Chardon, 1977). However, growers can reduce the occurrence of waterlogging through better management practices which include laser leveling blocks, improving drainage systems, planting on mounds, and planting earlier to avoid waterlogging when the crop is of less height (Reghenzani and Roth, 2006).

Planting varieties with waterlogging tolerance is beneficial and in combination with management practices offers the best approach to reduce the impact of waterlogging on productivity. If waterlogging is in early stage of crop growth it affects germination, tillering and cane growth which may result in crop failure. Generally, the waterlogging coincides with grand growth phase and may extend up to the crop maturity; and hence the early planted crop suffers less. Such canes record higher percentage of flowering and poor juice quality with low sucrose, high invert sugars, high non-proteinous nitrogen and total colloids. Therefore, to meet the immediate need of sugarcane farming community and sugar factory, there is a need of more number of mid-late maturing, high sugar clone having high tolerance to waterlogged conditions to meet the challenges for improving sugar recovery, especially during the mid-late of the crushing season. Hence, the research efforts were made to identify mid-late maturing clones tolerant to waterlogged conditions with sustained high cane and sugar yields in India.

MATERIALS AND METHODS

Study areas

The experiment was conducted with 16 genotypes procured from Sugarcane Research Institute, D.R.P.C.A.U. Pusa, Samastipur, Bihar (India) during spring 2016-2017. The experimental plot was situated between 25.97^0 N latitude and 85.66^0 E longitudes at 51.80 m amsl**.** In this region monsoon come in third or fourth week of June and continues up to September. The average rainfall is 1156.00 mm out of which nearly 972 mm is received during the monsoon extending from June to September. The experimental plot was well leveled but remains waterlogged during June to September 2016 due to low land. The average depth of water varied from 30 to 90 cm and 130 cm for 15 days during September, 2016. The month-wise temperature, relative humidity and rainfall during the period was recorded.

Treatments and experimental design

The 16 sugarcane clones *viz*., CoP 09437, CoP 11439, CoP 11440, CoP 12438, CoP 12439, CoP 13438, CoP 13439, CoP 14438, CoP 14439, CoP 15439, CoP 15440, CoP 15441, BO 155 and CoP 2061 were evaluated along with 2 standard checks BO91 and BO154. The trial was laid out in a randomized block design with three replications. All the experimental materials were developed at SRI, Pusa, Bihar. Equal number of three budded set of each clones was planted.100 sets of three budded were planted in four furrows spaced at 90 cm from one another and the length of furrow in each plot was 6 m (plot size $6 \times 4 \times 0.9 \approx 21.6$ m^2). The fertilizer dose applied was 150 kg N, 85 kg P_2O_5 and 60 kg K_2O ha^{-1}. Half the N, total P_2O_5 and K_2O was applied as basal dose while rest of N was applied in two split doses one 60 days after planting and other at the time of earthing up (120-150 day after planting). Sets were treated for 10 min in carbendazim @ 1 g L^{-1} water. Before covering of setts 15 kg Phorate 10G was applied to control the infestation of termites and other insects.

Data collection and analysis

Data were collected for yield attributing traits *viz*., germination percentage at 45 DAP (days after planting), number of shoots at 120 DAP, plant height at 150, 240 and 360 days, number of fully emerged leaves at 30 and 60 days after waterlogging, leaf area index before waterlogging, at 30 and 60 days after waterlogging, number of nodes with aerial roots, cane diameter at harvest, number of shoots at 240 DAP, number of millable canes at harvest, single cane weight, cane yield and sugar yield at harvest and juice quality traits at 10 and12 months stage and CCS % at 10 and 12 months stage. Chemical analyses of sugarcane juice for brix %, pol %, estimate for sucrose, purity % and CCS % were done. Randomly selected 5 sample cane stalks were crushed with a minipower crusher to get juice for analysis, was taken by Brix hydrometer made in Germany (N.CH.W.) standardized at 20^0C and pol % determination was done by taking approximately 100 mL juice of each sample was taken in a beaker and about 1-1.5 g basic lead acetate anhydrous was added to it, stirred and kept for some time for the precipitation of non- soluble substance. The precipitated impurities were filtered off and clear filtrate juice was collected. The clear filtered juice was filled in 20 cm long polarimeter tube. This tube was placed in the body of polarimeter and pol reading was recorded. Using Schmitz table (Spencer and Meade, 1955), the sucrose percent in juice was noted for corresponding values of the brix and pol reading. CCS % is determined by formula:

$$\text{CCS \%} = [S-(B-S) \times 0.4] \times 0.73$$

Where, S = Sucrose percent in juice (pol %); B = Brix percent in juice

Heritability (Broad sense) and genetic advance

Heritability in broad sense was estimated by the formula given by Johnson *et al.* (1955). The heritability was categorized as low, moderate and high as given by Robinson *et al.* (1949). The estimates of genetic advance were obtained by the formula given by Lush (1949) and Johnson *et al.* (1955). The range of genetic advance is classified as suggested by Johonson *et al*. (1955).

Selection indices

Selection indices was estimated as per the formula given by Smith (1936). Rank coefficient of correlation was calculated by formula given by Spearman (1904). The computed values of correlation coefficient were tested for significant at (n-2) degree of freedom as specified level of significance (1%) where ‘n’ denotes the number of clones used in this investigation. If the observed value is more than the tabulated value the correlation coefficient is said to be significant.

RESULTS AND DISCUSSION

The month-wise temperature, relative humidity and rainfall during the period is presented in Fig. 1.

Heritability and genetic advance

Moderate to high heritability estimates were noticed for all the characters studied, except number of nodes with aerial roots, (Fig. 2) thereby suggesting that selection of clones for these characters will be effective. This is in agreement with Tena *et al.* (2016) who found high broad sense heritability for stalk diameter, single cane weight, millable cane weight, stalk height and pol %. Gowda *et al.* (2016) reported that cane yield components *viz*., sugar yield number of millable cane, single cane weight and cane yield showed high heritability but their results are slightly different for plant height, stalk diameter, brix percentage pol percentage, purity percentage and CCS percentage. The difference might be due to environmental variations in expression of these traits.

Genetic advance as percent of mean was high for sugar yield (CCS t ha^{-1}), cane yield, leaf area index before waterlogging and leaf area index at 30 and 60 days after waterlogging (Fig. 2). It was moderate for germination percentage at 45 DAP, number of shoots at 120 and 240 DAP, number of millable cane at harvest and plant height at 150, 240 and 360 DAP, thus revealing the role of dominant genetic effect in determination of these characters and its improvements. The results are in conformity with Singh *et al.* (1996) for cane yield, cane diameter, cane height and number of millable cane. However, our results slightly differ from the findings of Kumar *et al.* (2001) for number of millable cane and single cane weight which might be due to environmental difference. Bairwa *et al.* (2017) found moderate genetic advance as percent of mean for trait cane diameter these finding are in agreement with present investigation.

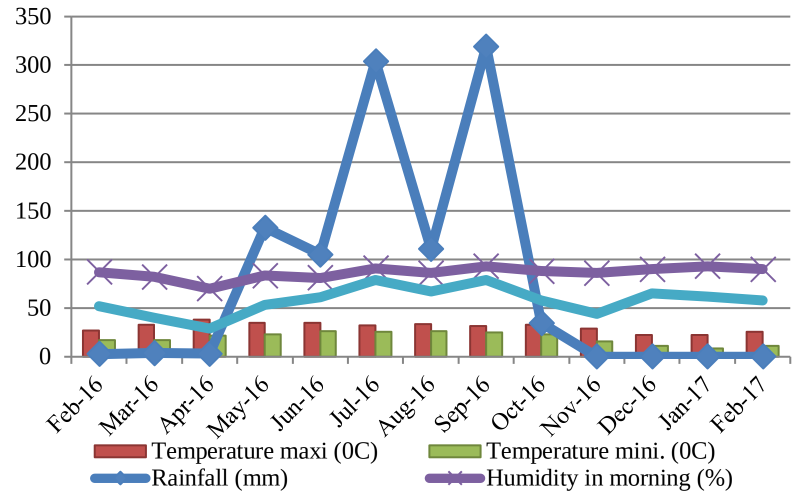

Fig. 1: Meteorological data recorded monthly during cropping season 2016-17 (Source: Dept. of Agro meteorology, DRPCAU, Pusa, Samastipur, Bihar)

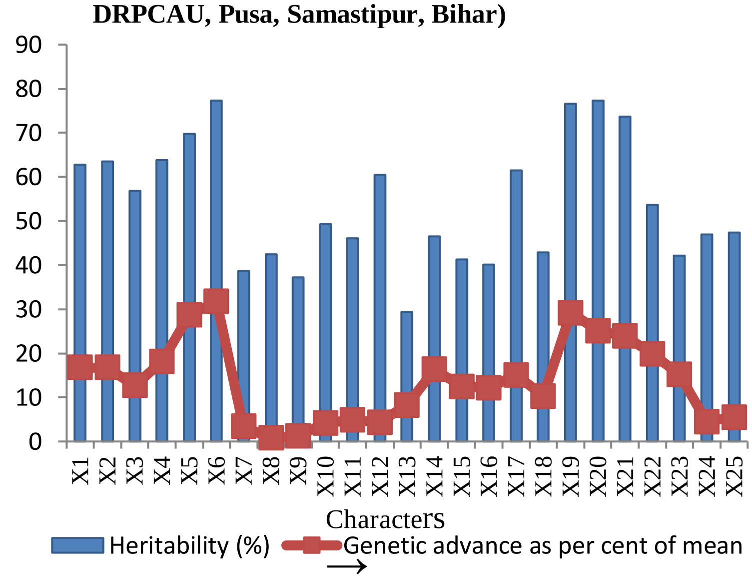

Fig. 2: Histogram depicting estimates of heritability and genetic advance as per cent of mean for 25 traits of 16 sugarcane clones under waterlogging condition. X1 - Germination %age at 45 DAP; X_2 - No. of shoots at 120 DAP; X_3 - No. of shoots at 240 DAP; X_4 - No. of millable canes at harvest (000 ha^{-1}); X_5 - Sugar yield (t ha^{-1}); X_6 - Cane yield (t ha^{-1}); X_7 - Brix % at 12 months stage; X_8 - Purity% at 10 months stage; X_9 - Purity% at 12 months stage; X_{10} - Pol% at 10 months stage; X_{11} - Pol% at 12 months stage; X_{12} - Brix% at 10 months stage; X_{13} – No. of nodes with aerial roots; X_{14} - Plant height at 150 DAP (cm); X_{15} - Plant height at 240 DAP (cm); X_{16} - Plant Height at 360 DAP (cm); X_{17} - Single cane weight (kg); X_{18}- Cane diameter at harvest (cm); X_{19} - Leaf area index before waterlogging; X_{20} - Leaf area index (LIA) at 30 days after waterlogging; X_{21} - LAI at 60 days after waterlogging; X_{22} – No. of fully emerged leaves at 30 days after water-logging; X_{23} – No. of fully emerged leaves at 60 days after waterlogging; X_{24} - CCS% at 10 months stage; X_{25} - CCS% at 12 months stage

The results revealed the importance of traits such as sugar yield (CCS t ha^{-1}), cane yield (t ha^{-1}), leaf area index (LAI) before waterlogging, LAI at 30 and 60 days after waterlogging as they exerted high genetic advance in terms of percentage of mean coupled with high heritability, thereby indicated that these traits were controlled by additive gene action. Hence, phenotypic selection could be effective in the improvement of such traits. These finding are in agreement with those of Jain *et al.* (2001) and Pandey *et al.* (2010) for single stalk weight and cane yield. Kumar *et al.* (2004) found similar result for cane yield.

Mean performance

The mid-late clone BO2061 gave higher cane yield (88.8) and sugar yield (9.8) [Table 1]. The clones BO154, CoP2061, BO155, CoP15440, CoP14439, CoP14438, CoP12439 and CoP09437 produced >85 t ha^{-1} of millable canes. Clone CoP15439 showed higher mean performance for single cane weight, followed by clone CoP2061 and Bo155. Clone CoP15441 showed highest mean performance for cane diameter at harvest, followed by clone CoP15439 and CoP2061. The clone BO154 showed highest CCS percentage at 12 months stage followed by clone BO91 and CoP14438.

Table 1: Mean performance of 16 genotypes of sugarcane for 25 characters under waterlogged condition

Traits*/ Genotypes	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}	X_{22}	X_{23}	X_{24}	X_{25}
CoP 09437	38.0	95.7	133.1	88.5	9.0	76.3	19.3	87.4	88.3	15.9	17.1	18.2	6.0	72.7	239	248.7	0.9	2.4	2.1	2.9	3.5	9.3	10.7	10.9	11.8
CoP11439	32.7	82.0	115.0	71.1	6.1	55.1	18.5	86.6	86.6	15.8	16.2	18.3	6.3	82.7	189	204.3	0.8	2.3	1.7	2.0	2.3	8.7	9.7	10.9	11.1
CoP11440	30.3	77.3	120.0	60.0	6.1	49.0	20.1	87.3	89.6	16.7	18.0	18.9	6.3	87.8	171	186.4	0.8	2.4	1.7	2.2	2.2	8.3	9.7	11.5	12.5
CoP12438	36.5	81.0	137.2	74.8	6.0	53.4	18.7	86.6	87.5	15.8	16.3	18.2	6.7	88.7	210	222.7	0.7	2.1	2.2	3.0	3.8	11.3	12.0	10.8	11.3
CoP12439	42.3	101.8	157.2	92.9	7.6	67.5	18.7	87.9	87.6	15.8	16.4	18.0	5.7	108.7	228	248.0	0.7	2.2	2.0	2.8	3.4	8.7	9.7	10.9	11.3
CoP13438	33.7	87.7	140.7	73.0	6.7	59.8	18.5	87.2	87.8	15.3	16.3	17.5	5.3	89.4	167	182.7	0.8	2.1	1.5	2.3	2.9	7.7	8.0	10.5	11.2
CoP13439	32.3	91.3	131.3	78.7	6.4	58.2	18.5	87.5	87.0	15.8	16.1	18.0	5.3	75.2	196	207.7	0.7	2.1	1.7	2.6	3.1	7.0	9.3	10.8	11.0
CoP14438	40.7	94.0	147.2	89.2	8.9	74.2	19.7	88.7	88.4	17.3	17.4	19.5	6.0	81.2	176	186.1	0.8	2.2	1.7	2.5	3.0	10.0	11.7	12.1	12.0
CoP14439	35.0	93.7	138.6	85.5	8.9	78.7	19.0	87.3	86.3	16.5	16.5	18.9	7.0	96.3	195	211.4	0.9	2.6	2.4	3.2	3.5	9.3	11.0	11.4	11.3
CoP15439	36.4	104.2	143.0	82.7	9.1	82.9	18.3	88.1	87.3	16.4	16.0	18.6	7.3	102.8	213	196.6	1.0	2.7	2.4	3.1	3.5	11.0	12.3	11.3	11.0
CoP15440	42.5	106.2	155.7	89.6	8.7	74.5	19.6	86.8	86.0	16.0	16.9	18.4	6.7	99.9	216	231.7	0.8	2.4	2.1	2.8	3.0	11.0	12.7	11.0	11.5
CoP15441	38.7	85.3	130.3	77.1	7.6	68.4	18.3	86.8	87.4	15.1	16.0	17.4	6.7	77.6	194	211.9	0.9	2.8	2.1	2.7	3.0	8.3	10.0	10.4	11.0
BO 155	42.3	107.7	139.0	93.3	9.3	85.2	18.2	87.9	87.2	15.6	15.9	17.7	6.3	67.1	182	192.6	0.9	2.5	2.5	3.1	3.6	9.0	10.7	10.7	10.9
CoP 2061	41.3	105.1	152.3	95.2	9.8	88.8	18.6	87.5	86.7	15.7	16.1	17.9	5.3	79.3	247	261.3	0.9	2.6	2.7	3.2	3.4	8.7	11.7	10.8	11.0
BO 91	44.5	110.3	148.0	78.2	6.6	54.0	19.7	86.8	89.4	15.8	17.6	18.2	5.7	74.4	206	218.0	0.7	2.1	1.7	2.1	2.8	8.0	9.7	10.9	12.2
BO 154	39.0	105.7	160.3	93.2	9.7	79.3	19.8	86.9	89.1	16.2	17.7	18.6	6.7	90.2	224	238.6	0.9	2.4	2.1	2.8	3.3	11.7	13.7	11.1	12.3
GM (X)	37.9	95.6	140.5	82.7	7.9	69.1	19.0	87.4	87.6	16.0	16.7	18.3	6.2	85.9	203	215.5	8.8	2.4	2.0	2.7	3.1	9.3	10.8	11.0	11.5
SE (M)	1.7	4.3	5.8	4.0	0.5	3.8	0.4	0.3	0.6	0.3	0.4	0.2	0.4	6.2	13.5	14.1	0.1	0.1	0.1	0.1	0.2	0.7	0.8	0.2	0.3
$CD_{0.05}$	5.0	12.3	16.7	11.5	1.5	11.0	1.6	1.0	1.9	0.8	1.0	0.7	1.2	17.6	39.1	40.8	0.1	0.4	0.3	0.3	0.4	1.9	2.4	0.6	0.8
CV (%)	7.9	7.7	7.1	8.3	11.0	9.5	3.3	0.7	1.3	2.9	3.8	2.2	11.5	12.5	11.5	11.3	7.4	8.8	9.0	7.5	8.1	12.3	13.3	3.4	4.1

*Traits: X_1 - Germination %age at 45 DAP; X_2 - No. of shoots at 120 DAP; X_3 - No. of shoots at 240 DAP; X_4 - No. of millable canes at harvest (000 ha^{-1}); X_5 - Sugar yield (t ha^{-1}); X_6 - Cane yield (t ha^{-1}); X_7 - Brix % at 12 months stage; X_8 - Purity% at 10 months stage; X_9 - Purity% at 12 months stage; X_{10} - Pol% at 10 months stage; X_{11} - Pol% at 12 months stage; X_{12} - Brix% at 10 months stage; X_{13} – No. of nodes with aerial roots; X_{14} - Plant height at 150 DAP (cm); X_{15} - Plant height at 240 DAP (cm); X_{16} - Plant Height at 360 DAP (cm); X_{17} - Single cane weight (kg); X_{18} - Cane diameter at harvest (cm); X_{19} - Leaf area index before waterlogging; X_{20} - Leaf area index (LIA) at 30 days after waterlogging; X_{21} - LAI at 60 days after waterlogging; X_{22} – No. of fully emerged leaves at 30 days after water-logging; X_{23} – No. of fully emerged leaves at 60 days after waterlogging; X_{24} - CCS% at 10 months stage; X_{25} - CCS% at 12 months stage

The commercial cane sugar (CCS) per unit area of land gives the picture of the performance of a sugarcane clone. It includes both yield and juice quality of the clone. An ideal sugarcane clone should satisfy the requirement of cane growers in terms of yield as well as the mill management in

Table 2: Ranking of genotypes on the basis of three criteria

Genotypes	*Per se* performance cane yield	Score A	*Per se* performance sugar yield	Score B	Index value based on all traits	Score C
CoP 09437	76.3	6	9.0	5	4682.2	6
CoP11439	55.1	13	6.1	14	4512.4	15
CoP11440	49.0	15	6.1	14	4488.6	16
CoP12438	53.4	16	6.0	15	4634.6	10
CoP12439	67.5	10	7.6	9	4729.3	2
CoP13438	59.8	11	6.7	11	4553.4	14
CoP13439	58.2	12	6.4	13	4593.4	12
CoP14438	74.2	8	8.9	6	4604.6	11
CoP14439	78.7	5	8.9	7	4657.6	9
CoP15439	82.9	3	9.1	4	4693.4	5
CoP15440	74.5	7	8.7	8	4713.5	4
CoP15441	68.4	9	7.6	10	4587.7	13
BO 155	85.2	2	9.3	3	4668.6	7
CoP 2061	88.8	1	9.8	1	4736.8	1
BO 91	54.0	14	6.6	12	4662.8	8
BO 154	79.3	4	9.7	2	4728.7	3

Rank correlation coefficient (r) between A and B = 0.9610**; A and C = 0.6618**; B and C = 0.7375**

** Significant at 1 % level.

terms of recovery percentage. If both the traits are present in clone, then the state/national sugar productions will definitely increase. Taking account of the above comparison, the cane growers may be advised to grow the mid-late clones CoP2061 in waterlogging condition in order to get better economic return.

Selection indices

In order to make selection more effective, three criteria were used in present investigation *viz*., selection based on cane yield, selection based on sugar yield and selection index using all characters at a time. The rank correlation coefficient between these three criteria were highly significant (Table 2). Based on cane yield, the top-ranking clones were CoP2061, BO155 and CoP15439; while based on sugar yield CoP2061, BO154, BO155 and CoP15439 were better clones. Selection index prepared by using index value based on all traits, the top-ranking clones were CoP2061, CoP12439, BO154, CoP15440 and CoP15439. Considering all the characters and selection indices, the three best performing test clones under waterlogging conditions were CoP2061, BO155 and CoP15439.

Highly significant rank correlation between the selection index prepared on the basis of cane yield, sugar yield and all yield attributing traits showed that all the three criteria equally important for accessing the genotypic performance. Three clones CoP2061, BO155 and CoP15439 were selected and may be directly used as waterlogging tolerant clones and further utilized in breeding programme for developing high yielding with moderate to high sucrose containing clones tolerant to waterlogging conditions.

Conclusion: The greatest heritability in broad sense in tested sugarcane clones was exhibited by cane yield and lowest purity % at 12 months stage. All traits *viz.*, cane yield, leaf area index before waterlogging and 30 and 60 days after waterlogging, sugar yield, number of millable cane at harvest, number of shoots at 120 DAP, germination at 45 DAP, single cane weight and brix % at 10 months stage showed high genetic heritability in broad sense. High heritability coupled with high genetic advance was observed for cane yield, leaf area index before waterlogging and at 30 and 60 days after waterlogging and sugar yield, thus suggesting the preponderance of additive genetic effect in determination of these traits. Ranking of clones based on selection index and three other criteria revealed that clone CoP2061 was the most suitable one among the clones studied for waterlogging conditions. Other clones which withstood waterlogging situation were CoP15439 and BO155. These clones can directly be used as varieties for waterlogging tolerance as well as in crossing programme as parents to develop waterlogging tolerance clone.

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