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Research Article

Rice CR1009 *Sub* 1(IET 22187) - A new flood tolerant rice variety

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Abstract
CR1009 *Sub 1* a new version of long duration short bold grain rice variety CR1009 with submergence tolerance was released by Department of Rice, Tamil Nadu Agricultural University, Coimbatore, to overcome submergence during *samba* season for flood prone areas of Tamil Nadu. CR1009 *Sub*1 is a product of Marker Assisted Selection of the cross CR 1009 / FR 13 A and it was developed by IRRI in collaboration with NRRI, Cuttack. CR1009 *Sub1* rice variety recorded a mean grain yield of 5759 kg/ha with 8.90 per cent increase over CR1009. The variety was tested over three years in station trial (2008-2010), one year in Multi location trial (2010-11), two years in Adaptive research trial (2011-12 and 2012-13), two years in OFT (2010-11, & 2011-12) and one year in AICRIP trial (2010-11). CR1009 *Sub*1 is moderately resistant to BPH, WBPH, Brown spot and Leaf Blast. CR1009 *Sub*1 has short bold grain type with good milling percentage (69.8%) and head rice recovery (62.5%), high amylose content (25.0) intermediate gelatinization temperature and soft gel consistency indicating its similarity to CR1009 and also suitable for idly making. This variety was released by TNAU during 2015 and notified during 2017.

Key words
CR 1009 *Sub*1, long duration rice variety, short bold grain, MAS, QTL, Flood Tolerance

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Introduction

In Tamil Nadu, out of the about 17 lakh hectares of rice cultivation, three fourth is cultivated during samba season (Sep-Jan). During the favorable samba season, maximum area is occupied with medium and long duration varieties. In heavy rainfall period, of samba season an area of 2 to 3 lakh hectares is prone to flood due to North east monsoon rains and the water released from canals is not able to be drained and as a result submergence occurs. The tail end area of delta districts in Tamil Nadu *viz.,* Thiruvarur, Nagapattinam and Cuddalore are flood prone and due to this low productivity is recorded. CR1009 is the ruling variety in these regions. The rice variety CR1009 (IET 5897) was released by TNAU as an introduction in Tamil Nadu in 1982 and subsequently as Savithri by CRRI in 1983. The cultivation of this variety is in majority at Tamil Nadu due to the high preferences of farmers for its higher yield level. In general, the submergence exists upto 15 days which coincides with the vegetative stage of the crop at 30 days after transplanting and recedes later. If the flood water stagnation remains for more than a week, this variety is unable to sustain and thereby the yield levels are drastically reduced so that even up to of 50 % yield loss is observed. Hence, there is a need to develop flood tolerant rice variety to minimize the yield loss.

Research programme on the development of high-yielding flash flood tolerant rice varieties started as early as 1987 at the International Rice Research Institute (IRRI). Using a cross between an *indica* tolerant line (FR 13A) and a sensitive japonica line, Xu and Mackill (1996) mapped a major quantitative trait locus (QTL) associated with submergence tolerance on chromosome 9, accounting for 70% of the phenotypic variance in this population. Sequencing the *Sub1* region in an FR13A-derived line revealed the presence of three genes encoding putative ethylene responsive factors (ERF), *Sub1A*, *Sub1B* and *Sub1C.* Among them *Sub1A* was subsequently identified as the major determinant of submergence tolerance. Initially, this gene was successfully introgressed through marker-assisted backcrossing (MAB) into a popular high-yielding variety Swarna (Neeraja *et al.*, 2007). Due to the supremacy of Swarna *Sub*1 under flooded condition it was released as variety during 2009 in North East India. Successful adoption of Swarna *Sub*1 in North East India paved the way for the introgression of *Sub*1 locus into different backgrounds. An improved version of CR1009 with *Sub1* was also developed at IRRI following DNA based Marker Assisted Selection (MAS) by Septiningsih, *et al.* (2007) which was evaluated by Tamil Nadu Agricultural University in flood prone areas of Tamil Nadu. CR1009 *Sub*1

performed better than CR1009 under submergence conditions and matures in 155 days. This culture has good recovery after the relief of submergence stress and no yield penalty as that in CR1009 was observed. Multiple evaluations of submergence tolerance under greenhouse and farmers' fields confirmed these results (Sarkar *et al.* 2009). CR1009 *Sub* 1 has the potential to combat the submergence with 100% survival and high yield even in a prolonged submergence situation. Besides grain characters, reaction to pest and disease resistance are similar to CR1009. Therefore, CR1009 *Sub* 1 with higher yield and submergence tolerance in comparison with the check, CR1009 was released as a new variety for cultivation to overcome submergence during *samba* season for near flood prone areas of Tamil Nadu.

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Materials and Methods

CR1009 *Sub*1 is a Marker Assisted Selection product of the cross CR1009 / FR13 A and it was developed by IRRI in collaboration with NRRI, Cuttack. FR 13A, one of the parents used for the development of CR 1009 *Sub*1 was found to be highly tolerant and survive up to two weeks of complete submergence owing to a major quantitative trait locus submergence (*Sub*1) near the centromere of the chromosome 9. The physical position of *sub*1 locus in rice on chromosome 9 has been demonstrated by Neeraja *et al,* (2007) and Septiningish *et al.* (2007). The microsatellite marker RM 219 has been mapped at 3.4 cM from the gene and such identification in the genetic map appears to be suitable for selection of this gene. Seeds of CR1009 *Sub* 1 were received from IRRI through NRRI, Cuttack for assessing its performance in flood prone areas of Tamil Nadu. CR1009 *Sub* 1 was evaluated under different trials *viz.,* station trials from 2008-2010 (under submerged condition), Multi Location Trial (MLT) for one year during 2010-11 in 11 locations and Adaptive Research Trial (ART) in the farmers holdings during 2011-12 and 2012-13 in 54 locations across six flood prone districts of Tamil Nadu and On Farm Trial for two years 2010-11& 2011-12 under submerged and non submerged condition. Under All India Coordinated Rice Improvement Programme (AICRIP) the culture was tested during *kharif* 2010 in Advanced Varietal Trial–1-NIL-submergence trial. Physical, Milling and cooking quality characteristics of the culture were tested in the Department of Rice, TNAU, Coimbatore. Pests and diseases reaction was tested in TNAU Rice Research Stations at Coimbatore, Aduthurai, and Madurai.

Results and Discussion

At Department of Rice, TNAU, Coimbatore, CR1009 *Sub*1 recorded a mean grain yield of 6213 kg/ha over three years of station trials with 5.17 per cent improvement over CR 1009. Based on the performance in station trials, culture was nominated to multi location trial (MLT). CR1009 *Sub*1 was evaluated in MLT during 2010-11 in eleven locations which includes KVKs in flood prone areas of Tamil Nadu. In MLT, mean grain yield was 4605 kg/ha which was 22.73 per cent higher than CR1009. Under ART 2011-12 & 2012-13, CR1009 Sub1 was tested in six districts namely Thiruvarur, Nagapattinam, Cuddalore, Perambalur, Tanjore and Pudukkotai in Tamil Nadu of which the culture recorded more than 6000 kg/ha in 15 out of 54 locations tested. It recorded a mean grain yield of 5220 kg/ha which was 4.63 per cent higher than CR1009 in ART 2011-12 and 6205 kg/ha which was 5.92 per cent higher than CR1009 in ART 2012-13 (Table 1).

Large scale demonstrations alone helpful in assessing the full potential of the culture and OFTs are conducted. Under OFT, the culture recorded a mean grain yield of 5973 kg/ha which was 10.32 per cent higher than CR1009 during the year 2010-11 and 6652 kg/ha which was 11.40 per cent higher than CR1009 during the year 2011-12 in 25 locations in six districts (Table 1).The specificity of this variety to submergence tolerance was proved by its physiological efficiency. CR1009 *Sub*1 possess higher physiological efficiency by registering submergence tolerance index and less reduction of non structural carbohydrates, photosynthetic rate, transpiration rate and chlorophyll fluorescence ratio under 14 days of submergence compared to CR1009 (Table 2).

Non structural carbohydrate (NSC) content before and after submergence is important for providing substrates for generating energy for maintenance of vital metabolic processes during submergence and for regeneration and recovery of plants after submergence. In our study, CR1009 *Sub1* had a similar pre-submergence NSC to that of their recurrent parent CR1009. After submergence, they displayed significantly less reduction in NSC. Therefore tolerance of submergence were not necessarily associated with the initial carbohydrate status before submergence but rather with the ability to sustain a higher level of stored energy through either slow utilization during submergence and/or greater underwater photosynthesis (Mazaredo and Vergara 1982; Ram *et al.* 2002; Das *et al.* 2005; Sarkar *et al.* 2009; Gautam *et al.*2014). The cultivars that are able to maintain higher NSC at the end of submergence develop new leaves more quickly and accumulate greater biomass during recovery (Panda *et al.* 2008; Sarkar and Bhattacharjee 2012). Moreover, *Sub*1 introgression does not change the basic

carbohydrate content of the new lines, but instead regulates its maintenance and utilization during submergence.

CR1009 *Sub*1 had recorded higher photosynthetic rate, chlorophyll fluorescence ratio, stomatal conductance and transpiration rate under submergence. This could be due to *Sub 1* introgression which has improved the photosynthetic activity through less degradation of chlorophyll, higher stomatal conductance and efficient PSII activity (Chlorophyll fluorescence ratio) resulting in higher photosynthetic activity. Therefore the per cent reduction of the above physiological parameters was more pronounced in CR1009 compared to CR 1009 *Sub*1 (Table 2) .

CR1009 *Sub*1 is the medium tall genotype with a plant height of 112 cm. It has profuse tillering habit (16-20), with intermediate panicles length (23.5 cm) and complete grain fertility. Variety has dark greenish leaf with a length of 48.2 cm and breadth of 1.38 cm. This variety is characterized with erect flag leaf and well exerted panicle. Panicle type is intermediate with 218 number of grains/panicle and single plant grain yield of 50 to 60 g/plant. Grains are short bold with an L/B ratio of 2.05 and 1000 grain weight of 23g. Milled rice colour is white and abdominal white is occasionally present. Threshability of panicles is good and aroma is absent in grains as that of CR1009 *Sub*1 (Table 3).

Insect pests are major biotic constraint on rice production and causes significant yield losses every year in susceptible cultivars (Sogawa *et al.*, 2003). Brown plant hopper (BPH), white backed plant hopper (WBPH) and stem borer are important insect pests in rice growing areas of Southern India. The culture CR1009 *Sub*1 was evaluated for two years (2009-10 & 2010-11) at Coimbatore and Aduthurai against the major insect pests and recorded as moderately resistant to BPH (5) and WBPH (5) (Table 5a&b) Among diseases bacterial leaf blight, blast and brown leaf spot causes significant yield reduction. Bacterial leaf blight causes about 20-30 per cent loss, but in severe cases the yield may reduce upto 80 per cent (Perumalsamy *et al.*, 2010). Brown leaf spot is most serious disease in rice and yield loss may go upto 50-90 per cent (Arshad *et al.*, 2008) whereas 10-30 per cent loss was encountered every year due to bacterial leaf blight disease (Skamnioti and Gurr, 2009). The culture CR1009 *Sub*1 was screened against all the epidemic diseases *viz.*, blast, bacterial blight, sheath rot, sheath blight, brown spot and rice tungro disease (RTD) under artificially inoculated conditions during 2009-10 and 2010 - 11. The culture CR1009 *Sub1* is moderately resistant to brown spot (5) & Blast (5) (Table 4a & Table 4b).
The rice culture CR1009 *Sub*1 has short bold grain type with good milling percentage (69.8%) and head rice recovery (62.5%). It has high amylose content, intermediate gelatinization temperature and soft gel consistency. It is suitable for idly making (Table 6).

Hence, CR1009 *Sub*1 found similar to CR1009 in all aspects with enhanced submergence tolerance and a slight higher grain yield will be a boon to the farmers of target production environment like Cuddalore, Nagapattinam, Thiruvarur, Thanjavur, Pudukkotai and Perambalur of Tamil Nadu which are prone to flash floods due to water stagnation and poor drainage after the release of Cauvery water during NE monsoon rains. This variety was released by TNAU during 2015 and notified during 2017. So far 10 tonnes of breeder seed was distributed across Tamil Nadu which is slowly replacing CR1009. After the release of CR1009 *Sub* 1 during 2015, front line demonstrations (FLD) were conducted during 2015 and 2016 in Tiruvarur, and Nagapattinam districts.

During 2015, CR1009 *Sub*1 was evaluated under direct seeded condition in Tiruvarur and Nagapattinam districts of Tamilnadu, in 5 ha area under FLD. Even though there was a scanty rainfall in seedling stage and due to the NE monsoon rains, there was continuous water stagnation for 15 days till flowering. There was no yield penalty noticed in the variety CR 1009 *Sub1* and a grain yield of 5513 kg/ha with 6.6 % yield increase was observed. The farmers were satisfactory with this variety since there was no yield penalty and all the other attributes of this variety was similar to CR 1009, and readily accepted this variety (Table 7a).

During 2016, CR1009 *Sub*1 was introduced in the flood prone village Thalainayar on 20 ha areas, which is the very low lying area, succumbed with flood. The farmers raised the crop under direct seeded condition and due to in sufficient rainfall the crop did not suffered /affected by flood. But the intermittent rains helped the farmers to reap the crop with an average yield of 5468 kg/ha with 7.08% over CR 1009 and thereby proving that that CR 1009 *Sub1* performs well in drought besides submergence(Table 7b).

Under STRASA, during 2015, ten trials were conducted at Thanjavur, Tiruvarur and Nagapattinam districts in non-target locations with CR 1009 *Sub1* to estimate the yield penalty of CR 1009 Sub 1 in normal conditions. Results revealed that there was no yield penalty in CR 1009 *Sub 1*,

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instead a marginal increase of 3 to 4 percent over CR 1009 was realized. During 2016, thirteen trials were conducted in Kanyakumari district under transplanted conditions. Results revealed that there was marginal increase of 4.0 percent over CR 1009.

Salient features of Rice CR 1009 *Sub*1

- Long duration (155 days), high yielding semi dwarf rice variety with tolerance to submergence.
- Mean grain yield: 5759 kg/ha
- 15 out of 54 locations recorded more than 6000 kg/ha in Adaptive Research Trials
- Moderately resistant to Brown spot, Blast, BPH and WBPH
- Short bold rice with high milling percentage and head rice recovery, suitable for idly making

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Table 1. Over all yield performance of CR1009 *Sub*1 in different trials

Name of the trials	No of trials	Grain Yield (Kg/ha)		% of increase
		CR1009 *Sub*1	CR 1009	
Department of Rice, Coimbatore station trials	3	6213 (155)	5907 (156)	5.18
Multilocation trial 2010-11	11*	4605 (156)	3752 (158)	22.73
Adaptive Research trial 2011-2012	41@	5220 (154)	4989 (155)	4.63
Adaptive Research trial 2012-2013	13@	6205 (148)	5858 (147)	5.92
OFT 2010-11	25@	5973 (157)	5414 (160)	10.33
OFT 2011-12	25@	6652 (160)	5971 (162)	11.41
No of trials	118			
Over all weighted mean in kg/ha in all the trials		**5759 (155)**	**5290 (156)**	
Percentage increase over Check			**8.90**	

*Trials were subjected to submergence
@ A few trials were subjected to submergence
Figures in the parentheses indicates mean duration

Table 2. Physiological characters of CR1009 *Sub*1

Physiological characters	CR1009			CR1009 *Sub*1		
	Control	After 14 days of Submergence	% of reduction	Control	After 14 days of Submergence	% of reduction
Non Structural carbohydrates (Sugar+Starch) (mg/g)	65.00	39.75	38.8	63.14	50.14	20.6
Photosynthetic rate (µmol CO_2 M^{-2} S^{-1})	33.43	11.24	66.4	32.14	23.41	27.2
Stomatal conductance (mmol H_2O M^{-2} S^{-1})	13.8	4.7	65.9	12.4	8.9	28.2
Transpiration rate (mol H_2O M^{-2} S^{-1})	1.66	0.43	74.1	1.58	1.27	19.6
Chlorophyll Fluorescence ratio (Fv/FM)	0.75	0.37	50.7	0.73	0.64	12.3
SPAD value	40.12	18.41	54.1	39.37	31.24	20.7
Relative water content (%)	90.42	83.12	8.1	90.13	87.41	3.0
Submergence tolerance index (%)		70.0			100.0	
Submergence tolerance index (Visual Score)		1.0			5.0	

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Table 3. Morphological characters (DUS descriptors) of CR 1009*Sub1*

Characters	Remarks
Plant height (cm)	112.00
Basal leaf sheath colour	Green
Leaf sheath	Green
Leaf blade colour	Green
Leaf pubescence	Intermediate
Leaf length (cm)	48.2
Leaf width (cm)	1.38
Days to 50% flowering (days)	120-125
Panicle exertion	Well-exerted panicle
Stigma colour	White
Number of effective tillers	16 to 20
Panicle length (cm)	23.50
No. of grains/panicle	218
Panicle type	Intermediate
Awning	Absent
Days to maturity (days)	150 to 155
Seed coat (Kernel) colour	White
1000 grain weight (g)	23.00
Hull (husk) colour	Straw
Threshability	Good
Aroma	Absent
Grain yield per plant (g)	50 to 60
Grain	Short bold
LxB (mm)	5.06 x 2.46
L / B ratio	2.05
Rice grade	Short bold
Milled rice colour	White
Abdominal white	Occasionally present

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Table. 4a. Resistance reaction of CR1009 *Sub*1 against major rice diseases in 2009-10

Sl. No	Culture	Sheath rot	BLB	Brown spot	RTD	Blast
		ADT	ADT	ADT	CBE	CBE
1.	CR1009 *Sub*1	7	9	5	7	5
2.	CR1009	7	9	5	7	5

Table. 4b. Resistance reaction of CR1009 *Sub*1 against major rice diseases in 2010-11

Sl. No.	Culture	Sheath rot		BLB	Sheath blight		Brown spot	Blast
		ADT	CBE	ADT	ADT	CBE	ADT	CBE
1.	CR1009 *Sub*1	7	5	9	7	5	7	6
2.	CR 1009	7	7	9	7	7	7	6

BLB : Bacterial leaf blight RTD: Rice tungro disease
CBE : Coimbatore ADT : Aduthurai

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Table 5a. Resistance reaction of CR1009 *Sub*1 against major rice Pests in 2009-10

Sl. No.	Culture	BPH		SB
		ADT	MDU	CBE
1.	**CR1009 *Sub*1**	7	7	DH 6.25,WE 0.0
2.	**CR1009**	7	7	DH 6.25,WE 0.0

Table 5b. Resistance reaction of CR1009 *Sub*1 against major rice Pests in 2010-11

Sl. No.	Culture	BPH		SB	WBPH	GLH
		CBE	ADT	CBE	CBE	CBE
1.	CR1009 *Sub*1	5.0	4.77	DH 6.25 WE 0.0	5.0	5.0
2.	CR1009	5.0	4.77	DH 6.25 WE 0.0	5.0	5.0

BPH : Brown plant hopper WBPH: White backed plant hopper DH : Dead heart
GLH : Green leaf hopper SB : Stem Borer WE : White ear
CBE : Coimbatore ADT : Aduthurai

Table 6. Quality characteristics of CR1009 *Sub*1

a) Milling quality traits

Variety	Milling (%)	Head rice recovery (%)	1000 grain wt (g)
CR1009 *Sub*1	69.80	62.50	23.30
CR1009	69.27	62.00	21.96

b) Physical grain quality traits

Variety	Kernel length (mm)	Kernel breadth (mm)	L/B ratio	Grain Type
CR1009 *Sub*1	5.06	2.46	2.05	SB
CR1009	4.74	2.36	2.00	SB

c) Cooking quality traits

Variety	KLAC (mm)	KBAC (mm)	LER	BER	VE	GC	GT
CR1009 *Sub*1	9.2	3.3	1.74	1.03	4.4	Soft	Intermediate
CR1009	8.5	2.7	1.73	1.17	4.1	Soft	Intermediate

d) Biochemical properties of CR1009 *Sub*1

Traits	CR1009 *Sub1*	CR1009
Amylose content (%)	25.0	25.5
Crude protein (%)	9.20	9.12

e) Organoleptic evaluation of cooked rice

Characteristics	CR1009 *Sub*1	CR1009
Appearance	4.7	4.7
Cohesiveness	4.0	4.3
Tenderness on touching	4.0	4.0
Tenderness on chewing	4.1	4.0
Taste	3.0	3.4
Elongation	2.0	2.2
Overall acceptability	2.2	2.4

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Table 7a. Performance of CR1009 *Sub1* under submergence in front line demonstration (FLD) conducted during 2015-16

Sl. No	Name and address	Method of establishment	Area (ha)	Grain yield (kg/ha)		% increase over check
				CR1009 *Sub*1	ADT (R) 45 (Check)	
1.	Mr. I.Muthukumarasamy, Thirukuvalai Taluk, Nagapattinam Dt.	Direct sown	1.0	5115	5000	2.30
2.	Mr.R.Bandarinathan, Thiruvaimoor & post, Thirukuvalai Taluk,	Direct sown	1.0	5325	4800	10.93
3.	Mr.Ramalingam, Sitharkadu, Nagapattinam Dt	Direct sown	1.0	5900	5650	4.42
4.	B. Srinivasaragavan Muthupettai, Tiruvarur Dist.	Direct sown	1.0	5675	5315	6.77
5.	V.Venkatachalam Muthupettai, Tiruvarur Dist.	Direct sown	1.0	5550	4565	8.82
		Total	5.0	5513	5173	6.65

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Table 7b.Performance of CR1009 *Sub1* under front line demonstration (FLD) conducted during 2016-17

Sl. No	Name and address	Method of establishment	Area (ha)	Grain yield (kg/ha)		% increase over check
				CR 1009Sub1	CR 1009 Check	
1.	G. Rajendiran Thalainayar, Nagapattinam District	Direct seeded	1.00	6110	5880	3.91
2.	G. Vasudevan Thalainayar Nagapattinam District	Direct seeded	1.00	6100	5800	5.17
3.	M. Vinothharikrishnan Maracherry (Po), Thirukuvalai (Tk). Nagapattinam District	Direct seeded	1.00	5650	5300	6.60
4.	V. Josebinpunitha Thirukuvalai (Tk). Nagapattinam District	Direct seeded	1.00	6315	6170	2.35
5.	J. Vethamani, ,Kadanthethi, Nagapattinam District	Direct seeded	1.00	5550	4965	11.78
6.	B. Ilakiya, Kadanthethi Nagapattinam District,	Direct seeded	1.00	5985	5300	12.92
7.	M. Jeganathan Kadanthethi Nagapattinam District	Direct seeded	1.00	4900	4425	10.73
8.	K. Selvakumar Thalainayar Nagapattinam District	Direct seeded	1.00	5555	5100	8.92
9.	K. Sambath Thalainayar Nagapattinam District	Direct seeded	1.00	5824	5450	6.86
10.	S. Jawahar Nagapattinam District	Direct seeded	1.00	5605	5105	9.79
11.	S. Illayaraja Thalainayar Nagapattinam District	Direct seeded	1.00	5015	4700	6.70
12.	V. Sumathi Thalainayar Nagapattinam District	Direct seeded	1.00	4900	4600	6.52
13.	C. Gopalraj Thalainayar Nagapattinam District	Direct seeded	1.00	5360	5070	5.72
14.	G. Durgadevi Thalainayar Nagapattinam District	Direct seeded	1.00	5225	4900	6.63
15.	R. Iyappan Prinjumoolai, Nagapattinam District	Direct seeded	1.00	5010	4820	3.94
16.	R. Durairajan Prinjumoolai, Nagapattinam District	Direct seeded	1.00	5705	5200	9.71
17.	R. Chandrakumar Prinjumoolai. Nagapattinam District	Direct seeded	1.00	5520	5010	10.18
18.	P. Radharukmani Kadanthethi. Nagapattinam district	Direct seeded	1.00	5000	4885	2.35
19.	D. Kalaivani Prinjumoolai, Nagapattinam District	Direct seeded	1.00	4990	4750	5.05
20.	D. Soundarrajan Thalainayar 3- sethi, Nagapattinam District	Direct seeded	1.00	5040	4700	7.23
	Total		**20.00**	5468	5107	7.08

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