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ACKNOWLEDGEMENTS. We are grateful to Dr Billy Sinclair for comments on the earlier version of this manuscript. We thank Ms Wendy Dockerty for providing help in DNA extraction and Ms Robyn Taylor for technical support with AFLP. IPRS and UPRA scholarships to P. B. by CQU are acknowledged.

Received 24 March 2004; accepted 30 September 2004

Identification of sugarcane clones resistant to the sugarcane woolly aphid (*Ceratovacuna lanigera* Zehntner)

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Sugarcane woolly aphid (SWA) has become a serious pest in peninsular India, causing significant loss in cane yield and sugar recovery. The currently cultivated commercial varieties are susceptible, necessitating the need for finding resistant sources. The hybrid progeny population numbering 828, pre-selected from 45 crosses involving commercial varieties, were evaluated in field trials to isolate resistant clones with improved productivity. The hybrid progenies were evaluated over three hot spot locations for the SWA along with four commercial varieties. Nine progeny clones were totally free from aphid infestation and two clones had lower aphid load under natural infestation. When these clones were evaluated under artificial infestation, the nine clones confirmed their resistant reaction. Three clones, viz. SNK 44, SNK 61 and SNK 754 are promising for both cane and sugar yield with acceptable cane features. It is suggested to test these clones in large-scale yield trials to know their suitability for commercial cultivation as well as their utility in future breeding programmes aimed at incorporating woolly aphid resistance.

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SUGARCANE woolly aphid, *Ceratovacuna lanigera* Zehntner was first reported on sugarcane in 1897 from Java[1] and it is a serious pest of sugarcane in Asia[2–9]. In India, it has been reported as a pest on sugarcane from West Bengal, Assam, Nagaland, Sikkim, Tripura and Uttar Pradesh[10–15]. Since 2002, it has attained a serious status in Maharashtra and Northern Karnataka[16–18] and has also spread to Andhra Pradesh, Tamil Nadu, Goa, Kerala (pers. commun.), Bihar, Uttaranchal and Uttar Pradesh. It has resulted in significant loss in cane yield and sugar recovery[16–22] which has led to drastic reduction in sugar production, cane area and crushing duration, ultimately affecting the economy of sugar mills[19] (through results of survey conducted by N.S.K.).

To manage this pest, several control measures, viz. chemical, biological, cultural and host plant resistance have been suggested[16–23]. Among these, host plant resistance is of paramount importance as this approach is environmentally safe, more stable and viable[18,24]. Attempts to identify resistant sugarcane germplasm have been made in Taiwan, Philippines and Indonesia. In Taiwan varietal differences for aphid incidence and its biology were studied and indicated the variety ROC 1 to offer resistance to some extent, as it was associated with longer nymphal period and fewer progenies per adult[25]. In a similar study at Philippines, varietal differences in relation to aphid biology were reported[26]. In Indonesia a resistance breeding programme was initiated for SWA[27]. There are no reports available on the level of resistance for sugarcane woolly aphid in India. However, earlier studies reported relative susceptibility of genotypes[16,19] and varieties with lower nitrogen content, total soluble solids and higher silicon were reported less susceptible[11].

The present study was envisaged to isolate resistant clones with improved productivity from large hybrid progeny population derived from 45 crosses involving diverse commercial varieties. Pre-selected (for cane yield and HR Brix%) 828 hybrid progenies were evaluated with four commercial varieties, at three hot spot locations for the

Table 1. Performance of sugarcane hybrid progenies in respect of reaction to SWA (natural), productivity, HR Brix% and flowering behaviour

		Reaction to SWA (0–4 scale) at						Cane yield (t/ha)					HR Brix%					
		Sankeshwar			Ugar	Hosur		Sankeshwar		Ugar	Hosur		Sankeshwar		Ugar	Hosur		
Clones	Parentage	PC	RT -I	RT- II	PC	PC	RT-I	PC	RT	PC	PC	Mean	PC	RT	PC	PC	Mean	Flowering
SNK 44	Co740 × CoA 7602	0	0	0	0	0	0	105.6	92.8	73.9	118.0	97.6	19.95	19.80	17.75	16.80	18.58	$+_1$
SNK 49	Co740 × CoA 7602	0	0	0	0	0	0	109.6	103.6	81.6	121.7	104.1	16.30	18.40	19.55	17.15	17.85	$+_1^L$
SNK 57	Co740 × CoA 7602	0	0	0	0	0	0	94.8	85.3	73.3	121.9	93.8	14.75	17.45	20.65	17.10	17.49	$+_1$
SNK 61	Co 740 × MS 6847	0	0	0	0	0	0	94.9	85.1	73.5	118.2	92.9	18.80	19.25	21.20	17.50	19.19	$+_2^L$
SNK 124	Co 7704 × CoC 671	0	0	0	0	0	0	98.5	107.7	89.0	132.9	107.0	14.20	17.70	18.35	20.35	17.65	$+_1$
SNK 158	Co 7704 × CoC 671	0	0	0	0	0	0	105.6	89.0	74.2	118.1	96.7	15.55	17.40	19.95	18.60	17.88	$+_1$
SNK 192	Co 86249 × CoC 671	0	0	0	0	0	0	94.3	92.8	73.7	117.3	94.5	16.60	17.85	17.50	17.00	17.24	NF
SNK 256	Co 88028 × Co 88025	0	0	0	0	0	0	94.6	106.3	74.9	121.9	99.4	14.05	12.25	17.25	11.40	13.91	$+_1$
SNK 754	CoC 671 Poly Cross	0	0	0	0	0	0	98.5	107.6	70.5	121.8	99.6	20.00	20.20	21.20	17.00	19.60	$+_2^L$
SNK 250	Co 88028 × Co 88025	1	1	2	1	1	2	109.6	103.5	72.9	100.2	96.6	20.05	19.00	17.95	17.00	18.50	NF
SNK 335	CoC 671 × Co 88025	1	1	2	1	1	2	113.3	96.5	65.5	115.0	97.6	18.80	18.65	18.50	15.00	17.74	$+_2^L$
CoC 671		2	2	3	2	2	3	86.7	52.2	63.4	107.0	77.3	17.50	19.80	16.40	17.00	17.67	$+_2$
Co 86032		3	4	4	3	3	4	74.8	69.1	57.4	98.5	75.0	15.35	19.60	18.80	14.00	16.93	$+_2^L$
CD at 5%		–	–	–	–	–	–	06.7	10.5	09.8	09.0	–	00.96	00.26	00.91	00.22	–	–
CV %		–	–	–	–	–	–	10.2	18.0	16.1	10.0	–	02.58	00.66	02.21	01.61	–	–

PC, Plant crop; RT, Ratoon; HRB, Hand refractometer Brix%; $+_1$, Profuse flowering; $+_1^L$, Late and profuse flowering; $+_2$, Sparse flowering; $+_2^L$, Late and sparse flowering; NF, Non-flowering.

Table 2. Reaction of sugarcane hybrid progenies against SWA under artificial infestation

		Grade (colonization) at							
		Location 1 (Sankeshwar)				Location 2 (Hosur, Bijapur)			
Clones	Grade at release	7th DAR	15th DAR	21st DAR	28th DAR	7th DAR	15th DAR	21st DAR	28th DAR
SNK 44	4	0	0	0	0	*0	0	0	0
SNK 49	4	0	0	0	0	0	0	0	0
SNK 57	4	0	0	0	0	0	0	0	0
SNK 61	4	0	0	0	0	0	0	0	0
SNK 124	4	0	0	0	0	0	0	0	0
SNK 158	4	0	0	0	0	0	0	0	0
SNK 192	4	0	0	0	0	0	0	0	0
SNK 256	4	0	0	0	0	0	0	0	0
SNK 754	4	0	0	0	0	0	0	0	0
SNK 250	4	3	3	3	4	3	3	3	4
SNK 335	4	3	3	3	4	3	3	3	4
CoC 671	4	3	3	3	4	3	3	3	4
Co 86032	4	4	4	4	4	4	4	4	4

DAR, Days after release; *, Few aphids colonized initially soon after release and later gradually 100% mortality was observed (2–3 DAR).

Figure 1. A field view of an SWA resistant hybrid (healthy) SNK 754 (middle row) compared with susceptible hybrids (infested) on either side.

SWA, viz. Agricultural Research Station (ARS), Sankeshwar (Belgaum Dist), R&D farm of Ugar Sugars, Ugarkhurd (Belgaum Dist.) and Nandi Sugars, Hosur (Bijapur Dist.). The experiments were conducted over two crop seasons, viz. 2002–03 (clonal stage II PC and clonal stage I's ratoon I) and 2003–04 (clonal stage I's ratoon II and clonal stage II's ratoon I) in an augmented randomized block design. Each clone was grown in a 3 m row length spaced 90 cm apart with 10-eye buds m^{-1} seed rate. The data on cane yield, flowering and other cane features were recorded at 12 month and HR Brix% at 10 month crop age. Simultaneously, the clones were scored for SWA reaction on a 0–4 scale[16,19] under natural infestation (free choice condition) on the following basis: 0 = No Infestation; 1 = 1–25% leaf area covered with woolly aphid; 2 = 26–50% leaf area covered with woolly aphid; 3 = 51–75% leaf area covered with woolly aphid; 4 = 76–100% leaf area covered with woolly aphid.

Identified promising clones were evaluated under artificial infestation (no choice condition) at two locations, viz. ARS, Sankeshwar and R&D farm Nandi Sugars, Hosur for confirmation of pest reaction. Artificial screening was done during crop grand growth to early ripening stage (160–300 days after ratooning). Under artificial screening, five canes in each test clone were selected randomly and three leaves (middle and lower) of each cane were stapled with aphid-infested leaves comprising overlapping stages collected from severely infested crop (4th grade), avoiding natural enemies of the pest. The larval or pupal stage of predator, *Dipha aphidivora* Meyrick, was only observed in few aphid colonies and removed at the time of artificial release. The entire row of test clones and susceptible commercial varieties were caged to prevent entry of natural enemies and escape of released aphids. After releases were made, they were observed daily and observations recorded at a regular interval of 7 days up to 28 days after release, as the length of nymphal stage usually lasts for about 23–28 days[12,19,21,28,29]. Subsequently critical observations were continued till the crop harvest to confirm the nature of initial clonal reactions.

Out of 828 hybrid progeny clones evaluated, nine were free from aphids (0 grade) and two with lower aphid load (1–2 grades) compared to commercial check varieties (2–4 grades) (Table 1; Figure 1). All other progeny clones showed susceptible reaction with score ranging between 3–4 grades. Out of 11 (9 + 2) clones evaluated during 2003–04 crop season (Table 2), nine exhibited resistant reaction even under artificial infestation. The released aphids could not colonize on resistant clones even after 48–72 h (2nd–3rd day) of release, whereas, in susceptible genotypes including commercial varieties, aphids imme-

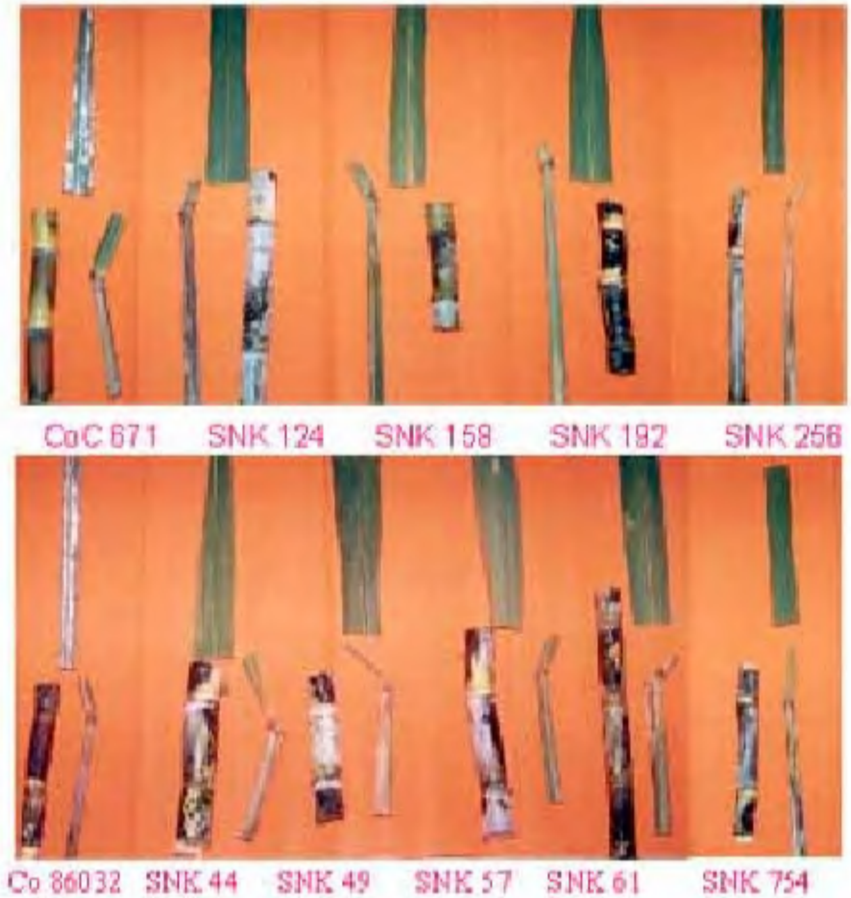

Figure 2. Healthy leaves and cane features of resistant clones compared with susceptible (infested) commercial varieties (CoC 671 and Co 86032).

diately colonized within 24 h after release. Though the clone, SNK 44 exhibited resistant reaction, partial colonization was observed in the initial stage soon after release at Hosur and 100% mortality of aphids was observed within 48–72 h (2–3 DAR). The aphids failed to survive and perpetuate on these resistant clones, indicating the possibility of operation of antibiosis and/or non-preference mechanism(s) in suppressing the pest and arresting further colonization and spread[24].

When the resistant clones were evaluated for their agronomic traits and juice quality (HR Brix%) over three locations, all the nine resistant clones recorded significantly superior cane yield compared to the best commercial check CoC 671 (Table 1). The clones, viz. SNK 44, SNK 61 and SNK 754 also recorded higher HR brix%, 18.58, 19.19 and 19.60 respectively compared to best check CoC 671 (17.67), indicating them to be the promising ones on the basis of both cane yield and sugar content with acceptable cane features (thick cane, loose clasping of leaves and non-spiny leaf sheath). The clone SNK 256, though recorded higher cane yield (99.4 t ha^{-1}), had lower HR Brix% (13.91) and non-acceptable cane feature (very thin canes) (Figure 2 and Table 1). Apart from high tonnage and sugar content, non-flowering/late-sparse flowering trait is the most desired feature for better field keeping quality[30,31]. SNK 61 and SNK 754 were late-sparse flowering types, suggesting their more promise for commercial cultivation.

Investigation of the underlying mechanisms of resistance operating in these clones can enhance the efficiency of resistance breeding. Some of these newly identified clones can be considered for commercial cultivation after confirming their superiority in large-scale trials. They will certainly serve as promising germplasm resources in breeding for resistance to woolly aphid in sugarcane.

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ACKNOWLEDGEMENTS. We thank staff of R&D unit and management board of Nandi Sugars, Hosur (Bijapur Dist.) and Ugar Sugars, Ugarkhurd, (Belgaum Dist.) for providing facilities to conduct clonal trials.

Received 15 March 2004; revised accepted 20 September 2004

Role of planning strategies in success/ failure of joint forest management plantation

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Joint Forest Management (JFM) relies on low cost option for regeneration of degraded forest patches. We review here criterion-based assessment of these community developed carbon sinks in four villages of Narmada district, Gujarat. Forest villages were ranked based on primary and secondary plant analysis, carbon sequestration rate, forest per household, landless families and gochar land available per Animal Cattle Units (ACU). Weightage was given to each criterion and changing the weightage value resulted in the changes in rank of the villages. This study highlighted the significance of planning strategy in success or failure of any JFM activity in restoration of forest areas of these villages.

FOREST policies like Wild Life Act 1972, Forest Conservation Act 1980 and the Forest Policy 1988, have contributed significantly in conserving forests and have triggered several afforestation programmes[1–4]. Joint Forest Manage-

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