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Research Article

CoPb 96: An early maturing sugarcane variety for Punjab

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Abstract
Sugarcane CoPb 96, an early maturing clone is developed at PAU Regional Research Station, Faridkot from segregating F_{1s} of general collections of Co 0238. It recorded commercial cane sugar (CCS t/ha), cane yield (t/ha) and sucrose % of 11.10 t/ha, 90.56 t/ha and 17.92%, respectively in comparison with the standards viz., Co 0238, CoJ 64 and CoPb 92. It was significantly superior to all the commercial varieties in Punjab state trials and on par with Co 0238 under AICRP trials. CoPb 96 was identified as a high sugared variety with 12.55 % CCS and 19.03 % sucrose content in AICRP trials (2P+1R) of North West Zone and performed better than all standard varieties. This clone is tolerant against diseases (red rot, wilt, smuts, pokkah boeng and YLD) and less susceptible against borer complexes. It has erect medium yellow green colored cylindrical canes (~ 244.00 cm length, ~2.64 cm diameter) and with rhomboid bud. CoPb 96 was identified as an early clone in comparison with Co 0238 by SVRC, Punjab for realizing higher cane yield and sugar recovery in the State.

Keywords: CoPb 96 (CoPb 14181), CCS yield, SVRC, Sugarcane

INTRODUCTION

Sugarcane contributes ~75% of the world sugar production, and also plays an important role for bio fuel production (Anna Durai *et al*., 2020). Under diverse ecological conditions of India, it is grown in most of the states i.e. East Coast Zone (Orissa, coastal Andhra Pradesh and coastal Tamil Nadu), Peninsular Zone (Maharashtra, Karnataka, Gujarat, Madhya Pradesh, Kerala, interior Andhra Pradesh and plateau region of Tamil Nadu), North West Zone (Punjab, Haryana, western and central Uttar Pradesh, Uttarakhand and Rajasthan), North Central Zone (Eastern Uttar Pradesh, Bihar and West Bengal) and North East Zone (Assam and Nagaland) (Singh and Singh, 2021). In spite of continuous huge efforts in sugarcane research and development, low crop productivity is being observed in the Indian sub-continent (Kulkarni *et al*., 2010). It might be due to some lacuna of genetic potential of cultivars along with distinct and diverse nature of its cultivation. Sugarcane area, productivity and sugar recovery in Punjab state has been decreased from 96.00 thousands ha, 83.60 t/ha and 9.78% during 2017-18 to 91.00 thousands ha, 80.20 t/ha and 9.59% during 2019-20, respectively (Anonymous, 2019a; Anonymous, 2021a). With this kind of fluctuating situation, the release of new improved varieties are required for sustaining the productivity and genetic improvement in cane yield and sugar recovery.

A continuous effort is being made by ICAR- Sugarcane Breeding Institute including SAU's (State Agricultural Universities) and other Sugarcane Research and

Development Centres to develop new cultivars. The varietal development program is considered to be satisfactory with suitable and appropriate breeding methods and techniques; through which improved varieties are identified (Abuellail *et al*., 2021; Singh and Singh, 2021). In this context, classical methods i.e. sexual hybridisation and selection still has the significant role in varietal development programmes (Anna Durai *et al*., 2015). All sugarcane breeding centres are engaged in the perfection of breeding techniques with the main objective to increase sucrose and cane yield. However, the aim is to attempt more number of crosses, lessen the plant mortality rate at every stage of the selection and adoption of better statistical methods for comparison and testing of clones (Saravanan *et al*., 2021). Different views are expressed from different breeders in favour of using proven parents and or cross combinations (Singh and Singh, 2021). The present study was designed to evaluate improved progeny from general collection population of wonder cane variety Co 0238 and its suitability for release as variety.

Sugarcane is an important industrial crop and more number of varieties with different maturity groups is required to meet the requirements of farmers and industries. Proper varietal planting schedule is always required to ensure quality cane supply to the factories throughout the crushing period for their economic sustainability (Solomon *et al*., 2007). In India, cane crushing season starts from mid-November to April-May months with varying environmental temperature range. Cane juice quality deterioration is high during late crushing months i.e. March and onwards as compared to early crushing months i.e. November to February due to sucrose inversion and dextran formation. Therefore, development of early maturing clones are essential to maximize quality sugar production. To cater the need and requirement of early maturing clones in North West Zone especially for Punjab state, the concentrated efforts had led to the development of new clone CoPb 96 (CoPb 14181) from Co 0238.

MATERIALS AND METHODS

Clonal selection was performed from F_1s segregating population of Co 0238 (GC's) to develop CoPb 96. The parental clone "Co 0238" identified by ICAR-SBI was released through CVRC as an early maturity variety and is the ruling sugarcane variety under North West Zone (NWZ) of India because of its high sugar and cane yield values. The genealogy of developed clone CoPb 96 is explained in **Fig. 1**. The crosses were attempted during November, 2008-09 at National Hybridization Garden (NHG), ICAR-Sugarcane Breeding Institute, Coimbatore (Tropical region of India, Peninsular Zone, 11°00′58″N/76°58′16″E). To identify elite clones for sugar and cane yield, seedlings were raised from fluff under controlled conditions (Poly House, by maintaining high temperature i.e. 35-40^{0}C and high humidity i.e. ~80-85%) during March - July (2009-10). By following recommended agronomic practices (Anonymous, 2021a), seedlings as well as further selected clones were generated and evaluated from Clonal 1 (2010-11) to advanced yield trials (2013-14) at Punjab Agricultural University, Regional Research Station, Faridkot (South Western Zone, 30°40'00''N/74°45'00''E), Punjab. The best clone identified was named as "CoPb 14181" and evaluated in Zonal Varietal Trials of AICRP in centres of North west zone during October 2014-15 and identified for release as variety at state/ national level of India under North West Zone.

CoPb 96, the accepted clone in the name of "CoPb 14181", was multiplied for one year i.e. 2015-16 at ICAR-SBI-Regional Centre, Karnal to supply enough cane seed to all nine evaluating centres of AICRP(S) NWZ of India. CoPb 14181 along with six other clones were evaluated against three standards (CoJ 64, Co 0238, Co 05009) in Initial Varietal Trials (IVT) during 2017-18 (Anonymous, 2018). Next year based on cane yield, sugar yield as well as reactions to diseases and insect-pests, four clones i.e. CoPb 14181, Co 14034, CoLk 14201and CoPb 14211 were selected for further evaluation and identification for release as variety against same set of standards in three consecutive Advanced Varietal Trials (AVT-I Plant, AVT-II Plant & AVT Ratoon) from 2018-19 to 2019-20 (Anonymous, 2019; Anonymous, 2020). In addition during 2020-21, CoPb 14181 was evaluated at Faridkot and Kapurthala centers of PAU, Ludhiana. All the experiments (Crop Improvement, Agronomy, Pathology and Entomology) were laid out in a randomized block design (RBD) with three replications and a plot size of 6/8 rows x 5.4 meters row length x 0.90 meters row to row spacing in IVT and AVT trials, respectively. As per technical programme, the recommended packages of practices were adopted for raising a good and healthy crop stand during the crop seasons.

Data on germination % (Gm %), number of tillers (000/ ha), number of shoots (000/ ha), number of millable canes (NMC, 000/ ha) and cane yield (t/ha), were recorded on plot basis and expressed on hectare basis. While for taking observations on stalk length (cm), single cane weight (SCW, kg) and cane diameter (cm), five to six competitive canes were selected randomly from each plots. Juice quality parameters like brix (%), sucrose (%), purity (%) and commercial cane sugar (CCS %) was reported during mid-November and t mid-January of crop seasons as per the standard protocol (Meade and Chen, 1971). Cane yield (t/ ha) x CCS% /100 formula was used to calculate commercial cane sugar (CCS) yield (t/ ha). Red rot resistance (pathotypes CF 08 from 'CoJ 84' and CF 09 from 'CoS 767'), and smut resistance screening were performed by creating artificial environments. Sugarcane borer complex (early shoot borer, top borer and stalk borer) incidences were also recorded. Natural

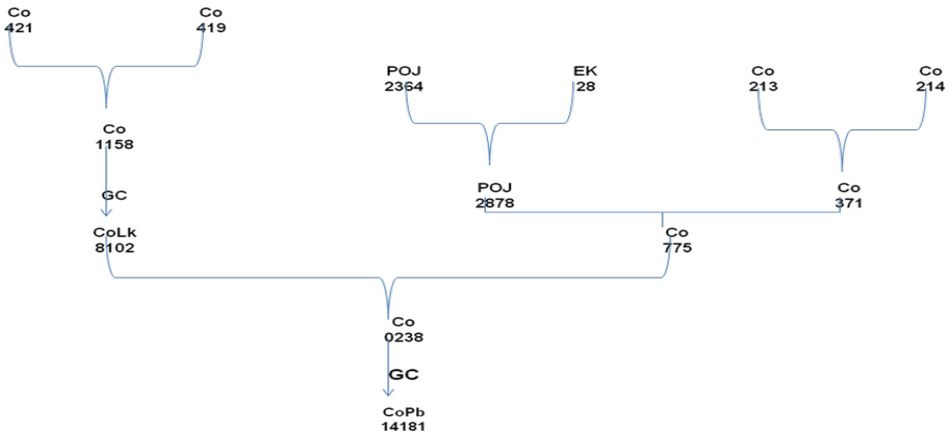

Fig . 1. Genealogy of Sugarcane Variety CoPb 96 (CoPb 14181)

incidences of diseases and insect pests in all the trials were also recorded. As per the guidelines of ICAR-AICRP, data were recorded and statistically analysed.

Data were analysed as per randomized block design analysis (Snedecor and Cochran, 1967) using different softwares (SAS, SPSS, CPCS1, OPStat, SPAR 2.0) by different AICRP(S) centres. 'F' test and critical difference (CD) at 5% level of significance was used to compare the significance of variation among the treatments. Variance analyses for each trait were based on linear model (Panse and Sukhatme, 1978) and interpretations were made accordingly.

RESULTS AND DISCUSSION

Significant differences (P>0.5) was observed among the testing clones with variance analyses over years and locations across Punjab states as well as across North West Zone of India (data given in PC Reports & PICI Reports of AICRP in IVT, AVT I Plant, AVT II Plant, AVT Ratoon and State Varietal trials for all traits (Anonymous, 2018; 2019; 2020). This indicated that positive clonal selection for genetic improvement could be performed (Singh and Singh, 2021). Significant differences among the testing clones for yield and quality characters have been reported along with improved improvement through selection (Anna Durai *et al*., 2020; Saravanan *et al*., 2021).

Weighted mean summary data across two locations (Faridkot and Kapurthala) on cane yield and its associated traits in State Varietal trials during 2017-18 to 2020-21 are provided in **Table 1**. Co 0238 was observed as the best standard for cane yield and SCW; while for juice quality traits, CoPb 92 was the best standard. CoPb 96 performed better than the standards for cane yield as well as juice quality traits. Based on IVT performance, four clones along with three standards (details given in materials and methods section) were selected for further evaluation in "AVT Plant & Ratoon" crops, identification and release of variety (Anonymous, 2018). Pooled data (2 plant crops + 1 ratoon) across nine locations on cane and sugar yield traits in AICRP trials of North West Zone comprising five states (Punjab, Haryana, Rajasthan, Uttarakhand and Uttar Pradesh) during 2018-19 to 2019-20 are given in **Table 2**. Co 0238 performed better than other standards while the performance of CoPb 96 among the test clones was better (Anonymous, 2019; Anonymous, 2020). CoPb 96 (CoPb 14181) showed a consistent better performance during three years of evaluation from 2018 to 2020 in plant as well ratoon trials (Anonymous, 2018; Anonymous, 2019; Anonymous, 2020). The cane characteristics of CoPb 96 in terms of NMC (000/ha), cane length (cm), cane girth (cm) and SCW (kg) was found to be similar to mega variety Co 0238 i.e. 87.38 thousands/ha, 243.87 cm, 2.46 cm and 1.25 kg, respectively (**Table 1**). The variety CoPb 96 as having parallel ideotype as mega variety Co 0238 could be considered as unique clones; if other superiorities like tolerance to biotic and abiotic stresses are being observed.

Farmers are mainly interested in cane yield advantages while sugar millers are interested in sugar recovery (Malik, 1994). Cane yield mainly depend on cane length and cane diameter (Naidu *et al.,* 2007) while juice quality mainly depends on the genetic nature of the clone (Yanam *et al*., 1997). Efficiency of dry matter partitioning in to sucrose should be better during the initial grand growth phase of the crop cycle especially for early maturing clones (Nayamuth *et al.,* 1999; Abuellail *et al*., 2021). Sugarcane clone CoPb 96 (CoPb 14181) has explained its performance in similar way as standards CoJ 64 and Co 0238 i.e. by exhibiting higher juice quality especially sucrose % along with comparative per se

Table 1. Weighted mean summary data (5 plant crops + 1 ratoon crop) of CoPb 96 (CoPb 14181) (across 2 locations) on cane yield and its associated traits in State Varietal Trials during 2017-18 to 2020-21

Varieties	Yield traits		Juice quality traits			Growth traits			
	CCS (t/ha)	Cane yield (t/ha)	Sucrose%	Purity%	CCS%	NMC (000/ha)	Cane length (cm)	Cane girth (cm)	SCW (kg)
CoPb 96	11.10	90.56	17.92	90.31	12.55	87.38	243.87	2.46	1.25
CoPb 92	10.69 (+3.87)	86.30 (+4.93)	17.91 (+0.06)	90.97 (-0.73)	12.54 (+0.08)	90.61	254.52	2.33	1.16
Co 0238	10.49 (+5.82)	88.63 (+2.18)	17.10 (+4.79)	90.49 (-0.20)	11.96 (+4.93)	81.25	238.10	2.71	1.30
CoJ 64	9.54 (+16.39)	76.94 (+17.70)	17.85 (+0.38)	91.20 (-0.98)	12.48 (+0.60)	89.72	228.27	2.39	1.01

Bold figure is the weighted mean; Value in parenthesis is the per cent increase/ decrease of CoPb 96 over checks.

Table 2. Pooled data (2 plant crops + 1 ratoon crop) of CoPb 96 (CoPb 14181) (across 9 locations) on cane and sugar yield traits in AICRP (S) trials of North West Zone during 2018-19 to 2019-20

At harvest (10 months)												
	CCS (t/ha)			Cane yield (t/ha)			CCS %			Sucrose%		
Entries	Mean (9)	Faridkot	Kapurthala	Mean (9)	Faridkot	Kapurthala	Mean (9)	Faridkot	Kapurthala	Mean (9)	Faridkot	Kapurthala
CoPb 96	10.46	11.58	9.87	83.50	90.98	77.55	12.55	12.75	12.74	19.03	18.99	18.89
CoJ 64	9.32	9.92	8.02	75.20	78.14	64.61	12.39	12.72	12.37	18.67	18.79	18.33
Co 0238	10.60	9.80	10.54	85.73	80.28	87.78	12.30	12.20	12.00	18.79	18.04	17.84
Co 05009	9.49	10.71	9.17	77.74	86.55	75.09	12.18	12.37	12.24	18.35	18.15	18.15

Bold figure is the weighted mean of AICRP(S) nine centres under North West zone.

performances for cane yield. In sugarcane both high sucrose content and retention of sucrose quality with the advance in age of the crop is important (Alexander, 1973). This kind of juice quality attributes has been observed in CoPb 96 (Anonymous, 2018; Anonymous, 2019; Anonymous, 2020).

Mean performance of CoPb 96 (CoPb 14181) at different recommended dose of fertilizers and spacings in Punjab state during 2018-19 to 2020-21 are given in **Table 3**. In comparison to wonder variety Co 0238, CoPb 96 (CoPb 14181) performed better both at fertilizer levels and spacings i.e. 112.40 & 94.90 t/ha at 90 cm and 120 cm spacings with recommended dose of fertilizers and 121.60 & 98.35 t/ha at 90 cm and 120 cm spacings with 25 % extra fertilizers of recommended doses, respectively. Cane yield differences due to fertilizers and spacing was observed less for CoPb 96 clone than others which proved the potential of the test clone CoPb 96 to grow in diverse management systems. However, its performance was comparatively better under less spacing along with higher dose of nitrogen fertilizer. So the higher cane yield advantages could be realized with more number of NMC per hectare.

Mean summary data (5 plant crops + 1 ratoon crop) of CoPb 96 (CoPb 14181) (across 2 locations) on insect-pest (natural conditions) and diseases (artificial conditions) in State Varietal Trials during 2017-18 to 2020-21 are given in **Table 4a.** CoPb 96 was observed to be resistant to both red rot and smut diseases. The new clone CoPb 96 is less susceptible to borer complex under natural conditions in comparison with the mega standard variety Co 0238. Field observations on natural incidence of different diseases are given in **Table 4b**. No natural incidence of diseases except pokkah boeng the wide spreading disease in most of the sugarcane clones were reported in CoPb 96.

A wide range of susceptibility reactions of sugarcane clones to diseases and insect pests are being reported since long back because of major role of environmental factors in its development (Ali *et al*., 2007; Radadia and Shinde, 2013; Kaur *et al*., 2016; Anonymous, 2018; Anonymous, 2019; Anonymous, 2020). Similarly, CoPb 96 has been observed “MR to R” to red rot, “MS” to smut and “LS” to borer complexes (Anonymous, 2018; Anonymous, 2019; Anonymous, 2020). Additional merit of CoPb 96 over the standards CoJ 64 and Co 0238 is attributed by its frost tolerance, non-lodging nature and

Table 3. Mean performance of CoPb 96 (CoPb 14181) for cane yield (t/ha) at different recommended dose of fertilizers and spacings in Punjab during 2018-19 to 2020-21

Row spacing (cm)	Fertilizer levels*	Years	Varieties				Mean**
			CoPb 96	CoPb 92	Co 0238	CoJ 64	
90 cm	100% N (150 kg/ha)	2018-19	105.6	105.1	87.5	74.1	102.9
		2019-20	-	-	-	-	-
		2020-21	119.2	95.1	120.4	87.7	106.7
	125% N (187.5 kg/ha)	2018-19	-	-	-	-	-
		2019-20	-	-	-	-	-
		2020-21	121.6	108.7	123.5	103.7	115.9
120 cm	100% N (150 kg/ha)	2018-19	95.1	86.5	94.1	75.3	98.6
		2019-20	91	-	71.9	63.9	75.6
		2020-21	98.6	83.8	92.1	71.8	85.1
	125% N (187.5 kg/ha)	2018-19	-	-	-	-	-
		2019-20	93.1	-	73.3	67	79.9
		2020-21	103.7	107	102.8	95.4	100.4
	Mean	2018-19	100.35	95.8	90.8	74.7	
		2019-20	92.1	-	72.6	65.5	
		2020-21	110.8	98.6	109.7	89.6	
				Year:	2018-19	2019-20	2020-21
				Genotypes:	9.9	11.2	14.6
	CD (5%)			Row spacing:	NS	-	5.9
				N levels:	-	NS	5.9
				Interaction:	NS	NS	NS

** Mean of trial having more number of varieties.
*In Punjab state, the recommended dose of fertilizers are only for nitrogen i.e. 150 kg N/ ha for plant crop, 225 kg N/ ha for ratoon crop. If the soil is low in available phosphorous, apply 30 kg P per ha at planting time.

Table 4(a). Mean summary data (5 plant crops + 1 ratoon crop) of CoPb 96 (CoPb 14181) (across 2 locations) on insect-pest (natural conditions) and diseases (artificial conditions) in State Varietal Trials during 2017-18 to 2020-21

				CoPb 96	CoPb 92	Co 0238	CoJ 64
Diseases under artificial conditions	*Red Rot disease	Plug method	CF08	3.7 MR	3.4 MR	3.5 MR	8.8 HS
			CF09	3.4 MR	3.6 MR	3.7 MR	8.6 HS
		Cotton Swab	CF08	R	R	R	MR
			CF09	R	R	R	MR
	**Smut disease			12.8 MS	14.3 MS	24.6 S	22.8 S
@Borer complex under natural conditions	^Early shoot borer (Natural)			6.86 LS	5.62 LS	7.27 LS	6.32 LS
	^^Stalk borer (Natural)			7.61 LS	6.01 LS	18.17 MS	6.97 LS
	^^^Top borer (Natural)			8.44 LS	6.57 LS	8.13 LS	7.4 LS

* Pathotypes: CF 08 from CoJ 84, CF 09 from CoS 767, R = Resistant (0-2), MR = Moderately Resistant (2.1-4), MS = Moderately Susceptible (4.1-6), S = Susceptible (6.1-8), HS = Highly Susceptible (>8)
**R = Resistant (0%), MR = Moderately Resistant (1-10%), MS = Moderately Susceptible (10.1-20.0%), S = Susceptible (20.1-30.0%), HS = Highly Susceptible (>30.0%)
@Per cent incidence based on dead-hearts recorded in post-germination phase at 30 days interval up to 120 days from sowing
@Cumulative per cent incidence during the 3rd and 4th broods (July, August and September)
@Per cent incidence at harvest (recorded on 75 canes per replication).
@Incidence of pyrilla, black bug and whitefly was observed in traces in the research trials on CoPb 14181 as well as the check varieties.
@Scale for incidence of sugarcane borers:
^Early shoot < 15 % Less susceptible, 15-30 % Moderate susceptible, > 30% High susceptible
^^Top borer < 10% Less susceptible, 10-20% Moderate susceptible, > 20% High susceptible
^^^Stalk borer < 10% Less susceptible, 10-15% Moderate susceptible, > 15% High susceptible

Table 4(b). Field observation of sugarcane variety CoPb 96 and checks to different diseases under natural conditions

S. No.	Disease	CoPb 96	CoPb 92	Co 0238	CoJ 64
1	Red rot	Nil	Nil	Nil	Observed
2	Smut	Nil	Nil	Observed	Nil
3	Wilt	Nil	Nil	Nil	Nil
4	Pokkah boeng	Observed	Observed	Observed	Observed
5	Ratoon stunting	Nil	Nil	Nil	Nil
6	GSD	Nil	Nil	Observed	Nil

better jaggery quality than CoJ 88. CoPb 96 has tall, medium thick, cylindrical yellow to yellow green canes with rhomboid shaped buds (**Table 5**). Farming communities and as well sugar mills are expecting new varieties with yield and quality improvement in comparison with wonder variety Co 0238 and this clone CoPb 96 with Co 0238 as a parent is expected to cater the needs of farmers , sugar mills and agro-industrial demands of sugar sector. (**Fig. 1 & 2**).

The weighted mean summary data (5 plant crops + 1 ratoon crop) of state varietal trials during 2017-18 to 2020-21 and pooled mean data (2 plant crops + 1 ratoon crop) of AICRP(S) trials during 2018-19 to 2019-20 indicated that CoPb 96 possess ideal cane ideotype characteristics with better tolerance to diseases and insect pests. Moreover, juice quality in this clone was numerically higher than the standards and ruling variety CoJ 64 and Co 0238 at 240 DAP and 300 DAP. The cane yield of CoPb 96 is on

Table 5. Distinguishing morphological characters (DUS Characters) of CoPb 96 (CoPb 14181)

S. No.	Traits	Descriptions	S. No.	Traits	Descriptions
1	Stalk (Cane) length (cm)	~244.00	24	Bud shape	Rhomboid
2	Habit	Erect	25	Bud hairs distribution	Absent
3	Tillers	$Medium	26	Bud cushion	Absent
4	wax band	Present	27	Bud groove	Absent
5	exposed color	Yellow	28	Bud extension	Above the ring
6	unexposed color	Yellow Green	29	Bud germpore	-
7	shape	Cylindrical	30	adherence	Medium
8	cross section	Round	31	color	Green yellow
9	diameter (cm)	~ 2.64	32	waxiness	Medium
10	length (cm)	~ 14.78	33	spines	Absent
11	waxiness	Medium	34	Ligule shape	Crescent
12	growth cracks	Absent	35	Auricle	Dentoid
13	corky patches	Absent	36	Dewlap color	Green
14	ivory marks	Absent	37	Leaf carriage	Open-tip curved (Arched type)
15	alignment	Regular	38	Lamina length (cm)	~ 162.5
16	Node swelling	Present	39	Lamina width (cm)	~ 5.43
17	Root zone color	Yellow	40	Lamina color	Green
18	Root zone width	~ 8.2 mm	41	Pithiness	Low
19	Growth ring color	*Yellow & Green Yellow	42	HR Brix at harvest	~ 20.00%
20	Growth ring prominence	Medium	43	Sucrose at harvest	~ 18.00%
21	Root eye rows	Two	44	Flowering	No
22	Root eye alignment	Alternate	45	Any other trait(s)	-
23	Bud size	Medium (~ 8.5 mm)			

Internode (S. No. 7–11); Leaf sheath (S. No. 30–33)

$(5-7 tillers per clump), *(Exposed & Unexposed, respectively),

Field view of CoPb 96

Clump **Bud** **Internode**

Fig 2. Field view, clump, bud and internode of CoPb 96

par with Co 0238; and it could be significantly increased through appropriate agronomical management practices especially by having less row to row spacing and or higher doses of nitrogenous fertilizers.

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