



## Minimization of post-harvest sucrose losses in drought affected sugarcane using chemical formulation

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### ABSTRACT

Sugarcane is a significant crop for production of sugar and ethanol in the world. In present perspective, drought is one of the frequently occurring abiotic stresses hampering the productivity of sugarcane causing heavy losses in sugar recovery. Post-harvest sugarcane deterioration attains more importance. Measures have been recommended in harvested canes to prevent these losses in general and under drought conditions but application of chemical formulation has not yet been tested over drought effected ones. Thus, we tried to investigate the efficacy of chemical formulation [Benzalkonium chloride (BKC) + Sodium metasilicate (SMS)] on sucrose losses occurring in harvested canes grown under drought and normal conditions. Results showed that application of chemical formulation had higher effect on drought canes in comparison to normal grown canes. Loss in cane weight was reduced to 8.25% and 11% in drought treated and normal treated grown canes, respectively, after 240 h of harvest in comparison to their respective control. In sucrose content and Commercial cane sugars %, drought treated canes showed an effect of BKC + SMS by reducing the losses to 1.26 units and 1.42 units, respectively, whereas in normal ones, reduction was of 0.38 units and 0.10 units, respectively. Biochemical analysis revealed that in reducing sugars, reduction in increase were of 44.51% and 25.50% in drought and normal grown canes, respectively, after 240 h of harvest. Dextran and soluble acid invertase estimations revealed that after application of BKC + SMS, reduction of dextran and invertase activity were of 49.74%, 66.84%, respectively, and 33.92%, 42.75%, respectively, in drought and normal grown canes, respectively. Total microbial load, showed effectiveness of 25.01% in drought grown canes while 14.41% in normal grown ones after 240 h of harvest. Our study was planned to use the anti-bacterial efficiency of both the chemicals over harvested canes so that the major sucrose losses occurring due to microbial deterioration could be inhibited. The use of this chemical formulation proves to be an effective one over post-harvest sucrose losses, particularly in drought grown canes.

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### 1. Introduction

Drought, one of vital abiotic stresses, is a frequent problem under the present climate change scenario and a severe danger

to productivity of agricultural crops all through the world (Ben et al., 2010; Santos et al., 2019). In the prevailing conditions of climate change, water tables are getting lowered day-by-day and occurrence of natural rainfall has also become scare affecting the productivity and production of crops (Kelkar-Khambete, 2014). Shrivastava et al. (2016) had focused that in 2015, half of the world faced the problem of drought causing heavy losses in crop yield and production. Increase in water stress has been reported to be the cause behind increasing global high temperatures. This in turn causes high evaporation rate resulting in adverse loss in water (Sugiharto, 2018). Studies have showed that inhibition in rate of photosynthesis (along with buildup of carbohydrates (Marcos

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et al., 2018)) and decrease in leaf turgor potentials are the major physiological reason behind the crop production and yield losses (Gong et al., 2005; Tahi et al., 2007; Özenç, 2008). Sugarcane is a commercial crop majorly for production of sugar and ethanol in the world. Although sugarcane has been blessed with certain natural abilities to tolerate such water deficit conditions yet sugarcane growth and development has been effected by drought condition (Shrivastava et al., 2017; Shrivastava et al., 2015). Studies had illustrated that stomatal closure, stalk inhibition, leaf senescence, leaf area reduction and leaf growth inhibition are few physiological responses which are widespread seen in water stress condition in sugarcane (Inman-Bamber and Smith, 2005; Inman-Bamber et al., 2012). Even Sugarcane drought responsive 2 gene (Sdr 2) has been identified playing role in response to such conditions (Begcy et al., 2019). Robertson et al. (1999) had reported that drought have the ability to reduce sugar losses up to 60%. In the year 2014–15, coverage of sugarcane has been reported to be 5.06 million ha but when drought occurred, the area coverage had reduced to 4.297 mha in 2015–16 and 4.503 mha in 2016–17 due to prevailing drought conditions in south India cane growing regions, particularly in Tamil Nadu, Maharashtra, Karnataka (Ram, 2017).

In accordance to this, post-harvest sucrose losses are common and a crucial problem of sucrose deterioration after harvest in canes. Several factors are responsible for these losses in sugarcane like weather conditions, time lag between harvesting and milling, variety, microbial infestation, etc. (Misra et al., 2016b; Solomon, 2009). About 20–30% of the total sucrose synthesized by this crop is lost due to its handling and its processing in sugar mills. In the recent years, this area has attracted widespread attention (Misra et al., 2016a; 2016b). Studies have shown that canes exposed to drought conditions had low sucrose content (Misra et al., 2016b), however, in respect to post-harvest sucrose losses, such conditions may further accentuates these problems and causes huge losses in sugar recovery. Although this could be managed to some extent in drought affected canes by preventive measures such as reducing the time lag between harvesting and milling, etc., but generally growers harvest their crop for growing up another crop and keep it in their fields for several days before being transported to mills (Solomon, 2009, 2006, 2000). Application of chemical formulation on drought affected harvested canes have not yet been studied. Therefore, the present study was aimed to minimize the post-harvest sucrose losses in canes grown under drought conditions by the application of Benzalkonium chloride (BKC) + Sodium metasilicate (SMS) chemical formulation. Benzalkonium chloride belongs to quaternary ammonium chloride compounds and it is the most active ingredient in disinfectants. It plays an effective action on bacteria, viruses, fungi and other microbes due to antibacterial property, it possess (Mayhall, 2004). Combination of BKC with sodium dodecyl sulphate has been tried on green and burnt whole stalks of sugarcane and was reported to be effective (Solomon et al., 2008). Sodium metasilicate has been used as an effective chemical ripener for sugarcane. Thus, this combination might help in inhibiting the sugarcane deterioration after harvest which could otherwise occurs at a faster pace due to the long time lag between harvesting to crushing as there is higher invasion of microbes through cut ends.

## 2. Materials and methods

The sugarcane crop was grown under two conditions, i.e., one under normal condition while other in drought condition in trench method of planting; following all proper cultural practices in month of February. The row to row spacing was kept at 75 cms. Soil was conventionally prepared. Basal dosage of fertilizer was also applied. Randomized block design of planting was adopted

for conduction of experiment. At the time of planting, soil had pH of 7.2, organic matter 0.43%, available N 188–250 kg/ha and P 30 kg P<sub>2</sub>O<sub>5</sub>/ha. Drought was imposed during tillering stage of the crop by skipping the irrigation. Fully mature cane crop, variety CoLk 94184 (also known as Birendra; parentage CoLk 8001 self) was harvested in the month of March. Due to high sugar content, early maturing, water logging and drought tolerant and covering a larger area of 10,000 ha in U.P. this variety has been selected for this study. A total of four piles of harvested sugarcane were made wherein two of normal grown canes while the other two of drought ones. In each sort of pile of canes, one pile was sprayed with the chemical formulation (1 L/pile). The chemical formulation was of Benzalkonium chloride + Sodium metasilicate (0.5%). After the spray was applied on to the canes, the canes were covered with sugarcane trash. Later different parameters were measured as required.

**Cane weight:** It was measured after harvest of canes of each pile and before extraction of juice to measure the loss in cane weight.

**Juice quality analysis:** Juice quality analysis was performed after 48 h of harvest, viz., 0, 48, 96, 144 and 240 h. Five canes from each pile were taken and juice was squeezed out with the help of roller crusher. Juice was collected in clean, dry and sterilized containers after which assessment of following juice quality parameters along with total microbial load were performed.

**Total soluble solids:** Total soluble solids were performed with the help of hand refractometer (Misra et al., 2016a).

**Sucrose percent:** Sucrose per cent was estimated using lead acetate method wherein 4 g of lead acetate was added to approx. 100 ml of juice and was left for precipitation. After which the juice was filtered through Whatmann filter paper and reading was taken in HORIBA polarimeter (Misra et al., 2016a).

**Purity coefficient, Commercial Cane Sugars (CCS) and recovery %:** Purity coefficient, commercial cane sugars and sugar recovery % were calculated by the formula mentioned below and sugar recovery % as per Tahir et al. (2014):

$$\text{Purity} = (\text{Sucrose}/\text{Brix}) * 100; \text{ Commercial cane sugars (\%)} = (1.022 * \text{Sucrose}) - (0.292 * \text{Brix})$$
 (Misra et al., 2016a);

**Biochemical analysis:** Reducing sugars were estimated with Nelson Somogyi method (Nelson, 1944). Estimation of dextran was performed by Haze method (Keniry et al., 1969). Soluble acid invertase activity was assessed by Santioparsi method (Rosarrio and Santioparsi, 2003).

**Microbial analysis:** Total microbial load was determined in treated and untreated canes grown in drought and normal grown conditions by nutrient agar medium. Serial dilution of juice was made and 100 µl of diluted juice was poured on nutrient agar plates which were sprayed uniformly through spreader. The plates were then incubated at 24–48 h at 37 °C for obtaining isolated colonies. Colonies were calculated manually by colony forming units/100 µl = No. of colonies obtained/100 µl.

**Statistical analysis:** The experiment was planned in randomized block design having three replications. Analysis of variance (ANNOVA) was performed using statistical software, CropStats 7.2 (IRRI, 2009).

## 3. Results and discussion

3.1. Efficacy of benzalkonium chloride (BKC) + Sodium metasilicate (SMS) chemical formulation spray on cane weight, °Brix, CCS %, sucrose % and purity coefficient

**Loss in cane weight:** In March harvested canes, in untreated normal grown sugarcane, the cane weight was 7.27 kg and with the increase in duration of staling this gets decreased further;

and after 240 h of harvest, the loss in cane weight value of 6.40 kg was observed. In Benzalkonium chloride + Sodium metasilicate (BKC + SMS) treated sugarcane, the cane weight was 7.27 kg at 0 h and with the increase in duration of staling this gets decreased further; and after 240 h of harvest, the loss in cane weight value of 6.47 kg was observed. This showed that there was a loss of 11.96% in untreated canes whereas there was a loss of 11.04% in BKC + SMS treated sugarcane (Fig. 1a). Similarly, in respect to drought sugarcane harvested in the month of March, the untreated canes showed a cane weight of 7.10 kg at the time of harvest. With the increase in duration of staling, the cane weight was decreased further. It was observed that after 240 h of harvest, the loss in cane weight value of 6.0 kg was observed, depicting a loss of 15.49%. In BKC + SMS treated sugarcane, the cane weight was 7.10 kg at 0 h and after 240 h of harvest, the loss in cane weight value of 6.50 kg was observed that showed a loss of 8.45% (Fig. 1b). On comparing the effect of drought on sugarcane in cane weight, the drought canes (15.13%) showed higher losses in cane weight in comparison to normal grown canes (11.96%) while application of the chemical treatment showed higher effect on drought canes (8.45%) than in normal grown canes (11.04%). Statistical evaluation showed that in cane weight, there was statistical significance on hourly basis between normal untreated and normal treated canes, however, no significant difference was seen on treatment basis (CD = 0.32; CV = 42.94; SE =  $\pm 0.11$ ). In drought untreated and drought treated canes, there was statistical significance on hourly basis, however, no significant difference was seen on treatment basis (CD = 0.30; CV = 43.19; SE =  $\pm 0.11$ ).

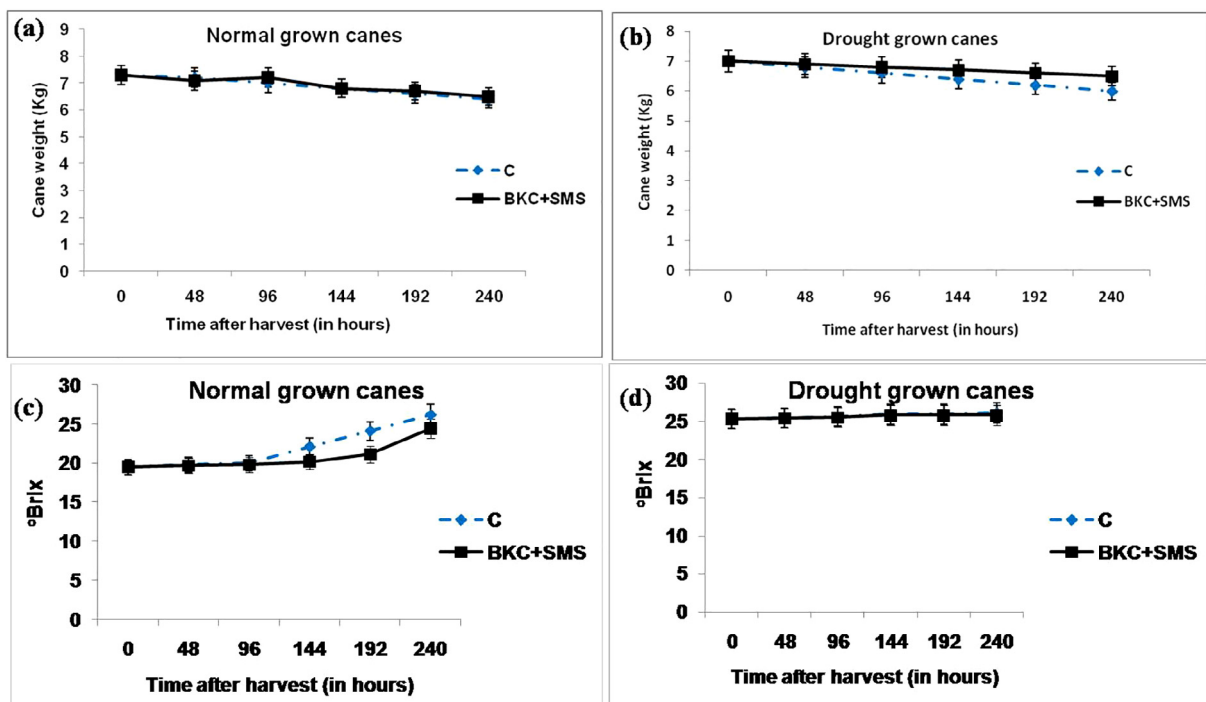
Cane weight is an important aspect for considering the assessment of cane staling (Solomon, 2000). Reports have shown that cane starts to lose its sucrose as it is being cut leading to loss in its weight. The percentage of loss in cane weight differs extensively. This variability is due to variation in temperature, humidity, speed of the wind of places along with varietal difference and storage method, etc. (Solomon, 2009). Solomon et al. (1997) have

revealed that under sub-tropical conditions, the loss in cane weight lies between 7.14 and 15 % with a maximum of 16–18% in the month of May and June after 120 h after harvest.

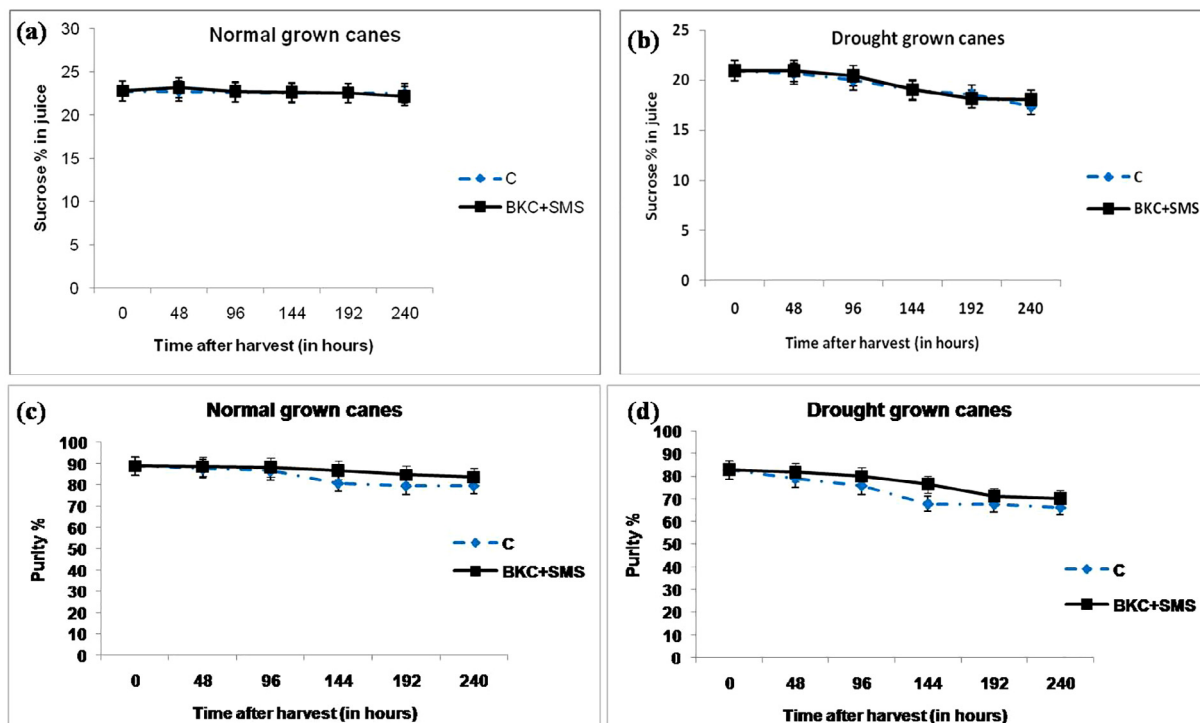
**$^{\circ}$ Brix:** In the untreated normal grown sugarcane,  $^{\circ}$ Brix was 19.53 and after 240 h of harvest  $^{\circ}$ Brix value of 26.19 was observed. In BKC + SMS treated sugarcane,  $^{\circ}$ Brix was 19.53 at 0 h and after 240 h of harvest,  $^{\circ}$ Brix value of 24.50 was observed. This showed that there was an increase in  $^{\circ}$ Brix by 34.1% and 25.44% after 240 h of harvest in normal and treated canes (Fig. 1c). Similarly, in drought sugarcane, the untreated ones showed  $^{\circ}$ Brix value of 19.45 at the time of harvest but after 240 h of harvest  $^{\circ}$ Brix value of 26.12 was observed. In BKC + SMS treated sugarcane,  $^{\circ}$ Brix was 19.45 at 0 h and after 240 h of harvest,  $^{\circ}$ Brix value of 25.80 was observed. This showed that there was an incline of 34.29% after 240 h of harvest in untreated canes while this increase was less in BKC+SMS treated canes (32.64%) (Fig. 1d). Statistical evaluation showed that in  $^{\circ}$ Brix, there was statistical significance on hourly basis between normal untreated and normal treated canes, however, no significant difference was seen on treatment basis (CD = 1.37; CV = 46.00; SE =  $\pm 0.49$ ). In drought untreated and drought treated canes, there was statistical significance on hourly basis, however, no significant difference was seen on treatment basis (CD = 1.37; CV = 46.41; SE =  $\pm 0.49$ ).

Our results were similar to Misra et al. (2016a) which revealed that there is higher amount of total soluble solids in drought affected canes in comparison to non-drought ones. Begum et al. (2012) had showed that there are two reasons affecting increase in brix, i.e., drought stage and genotypes in sugarcane exposed to such condition.

**Sucrose %:** At the time of harvest, in untreated normal grown sugarcane, the sucrose % was 21.12 and with the increase in duration of staling this gets decreased further; and after 240 h of harvest, the sucrose % value of 20.88 was observed. In BKC + SMS treated sugarcane, the sucrose % was 21.12 and 20.50 at 0 h and 240 h after harvest, respectively. This revealed that there was a



**Fig. 1.** Effect of post-harvest sucrose losses in sugarcane a & b: Loss in cane weight in normal and drought grown canes at an equal interval of 48 after harvest from 0 h till 240 h after harvest. The treatment tested was chemical formulation of benzalkonium chloride and sodium metasilicate (BKC + SMS) against untreated canes acting as Control (C); c & d: Increasing pattern of  $^{\circ}$ Brix in normal and drought grown canes at an equal interval of 48 after harvest from 0 h till 240 h after harvest wherein chemical formulation of benzalkonium chloride and sodium metasilicate (BKC + SMS) was tested against untreated canes acting as Control (C).



**Fig. 2.** Effect of post-harvest sucrose losses in sugarcane a & b: Loss in sucrose content in normal and drought grown canes at an equal interval of 48 after harvest from 0 h till 240 h after harvest. The treatment tested was chemical formulation of benzalkonium chloride and sodium metasilicate (BKC + SMS) against untreated canes acting as Control (C); c & d: Loss in purity coefficient (%) in normal and drought grown canes at an equal interval of 48 after harvest from 0 h till 240 h after harvest wherein chemical formulation of benzalkonium chloride and sodium metasilicate (BKC + SMS) was tested against untreated canes acting as Control (C).

decrease of 0.24 units after 240 h of harvest in untreated canes while this decrease was relatively lesser in BKC + SMS treated canes by 0.62 units in March harvests (Fig. 2a). Similarly, in untreated drought sugarcane harvested in the month of March, the sucrose % was 20.94 and after 240 h of harvest, the sucrose % value of 17.40 was observed. In BKC + SMS treated sugarcane, the sucrose % was 20.94 at 0 h and after 240 h of harvest, the sucrose % value of 18.06 was observed. This showed that there was a decrease of 3.54 units after 240 h of harvest in untreated canes while this decrease was relatively less in BKC + SMS treated canes (2.28 units) (Fig. 2b). On comparing the normal grown canes with drought ones, higher decrease of 3.30 units in sucrose of drought canes was seen but after the application of the treatment, sucrose % decreased lesser in both sorts of canes, viz., drought and normal canes, showing positive effect of the application of treatment, however, the drought canes (1.26 units) showed higher effect of the treatment than normal ones (0.38 units). Statistical analysis showed that in sucrose %, there was statistical significance on hourly basis between normal untreated and normal treated canes, however, no significant difference was seen on treatment basis (CD = 1.01; CV = 41.96; SE =  $\pm 0.36$ ). In drought untreated and drought treated canes, there was statistical significance on hourly basis, however, no significant difference was seen on treatment basis (CD = 0.92; CV = 44.01; SE =  $\pm 0.33$ ).

It has also been reported earlier that there is reduction in quality of juice obtained from water stressed canes along with declining pattern of sucrose per cent juice (Begum et al., 2012).

**Purity coefficient:** Purity coefficient in juice helps in determining the amount of sucrose content in per cent in Brix (Tahir et al., 2014). In untreated normal grown sugarcane, the purity coefficient was 88.89 whereas it was 79.72 after 240 h of harvest. In BKC + SMS treated normal grown sugarcane, the purity coefficient was 88.89 at 0 h and after 240 h of harvest this gets decreased to 83.67. This showed that there was a decline of 9.17 units after

240 h of harvest in untreated normal canes while this decrease was relatively lesser in BKC + SMS treated normal canes (5.22 units) (Fig. 2c). Similarly, in untreated drought sugarcane harvested, the purity coefficient was 82.68 and after 240 h of harvest, the purity coefficient was decreased to 66.61. But in BKC + SMS treated drought sugarcane, the purity coefficient was - 82.68 at 0 h and after 240 h of harvest, this value decreased to 70.0. This indicated that there was a decline of 16.07 units after 240 h of harvest in untreated drought canes while this decrease was relatively less in BKC + SMS treated drought canes (12.68 units) (Fig. 2d). Comparative evaluation revealed that drought grown canes (8.06 units) had higher effectiveness of chemical formulation applied than the ones grown in normal condition (3.95 units). Statistical evaluation showed that in purity coefficient, there was statistical significance on hourly basis between normal untreated and normal treated canes, however, no significant difference was seen on treatment basis (CD = 3.91; CV = 45.09; SE =  $\pm 1.40$ ). In drought untreated and drought treated canes, there was statistical significance on hourly basis, however, no significant difference was seen on treatment basis (CD = 3.91; CV = 51.11; SE =  $\pm 1.39$ ).

Similarly, Uppal et al. (2006) had also revealed decreasing pattern of purity % in cane juice. The decrease in pattern in purity coefficient is related to presence of bacteria in juice (Steel and Trost, 2006). Contrastingly, Parashar (1960) had also showed that in the later part of the cane season, the purity coefficient in non-drought canes is rapidly increased and this rapid increase is relatively lesser than the increase in  $^{\circ}$ Brix.

**Commercial cane sugars (CCS %):** Commercial cane sugars is an important aspect while analyzing the post-harvest sucrose losses as it determines the amount of commercial available sugars from sugarcane (Misra et al., 2016a). In untreated normal grown sugarcane, the CCS % was 15.88 and with the increase in duration of staling this gets decreased further; and after 240 h of harvest, the CCS % value of 13.69 was observed. In BKC + SMS treated sug-



arcane, CCS % was 15.88 at 0 h and with the increase in duration of staling this gets decreased further; and after 240 h of harvest, the CCS % value of 13.79 was observed. This showed that there was a decrease of 2.19 units after 240 h of harvest in untreated canes while this decrease was relatively lesser in BKC + SMS treated canes (2.09 units) (Fig. 3a). Similarly, in untreated drought sugarcane harvested, the CCS % was 13.98 and after 240 h of harvest, the CCS % value of 8.44 was observed whereas in BKC + SMS treated sugarcane, the CCS % was 13.98 at 0 h and after 240 h of harvest, the CCS % value of 9.86 was observed. This revealed that there was a decrease of 5.54 units after 240 h of harvest in untreated canes while this decrease was relatively lesser in BKC + SMS treated canes (4.12 units) (Fig. 3b). On comparing the efficacy of the treatment, the drought affected treated canes (1.42 units) showed relatively higher effect than the normal treated ones (0.10 units) with respect to untreated canes. Statistical analysis showed that in CCS %, there was statistical significance on hourly basis between normal untreated and normal treated canes, however, no significant difference was seen on treatment basis ( $CD = 0.69$ ;  $CV = 43.24$ ;  $SE = \pm 0.25$ ). In drought untreated and drought treated canes, there was statistical significance on hourly basis, however, no significant difference was seen on treatment basis ( $CD = 0.69$ ;  $CV = 54.65$ ;  $SE = \pm 0.25$ ).

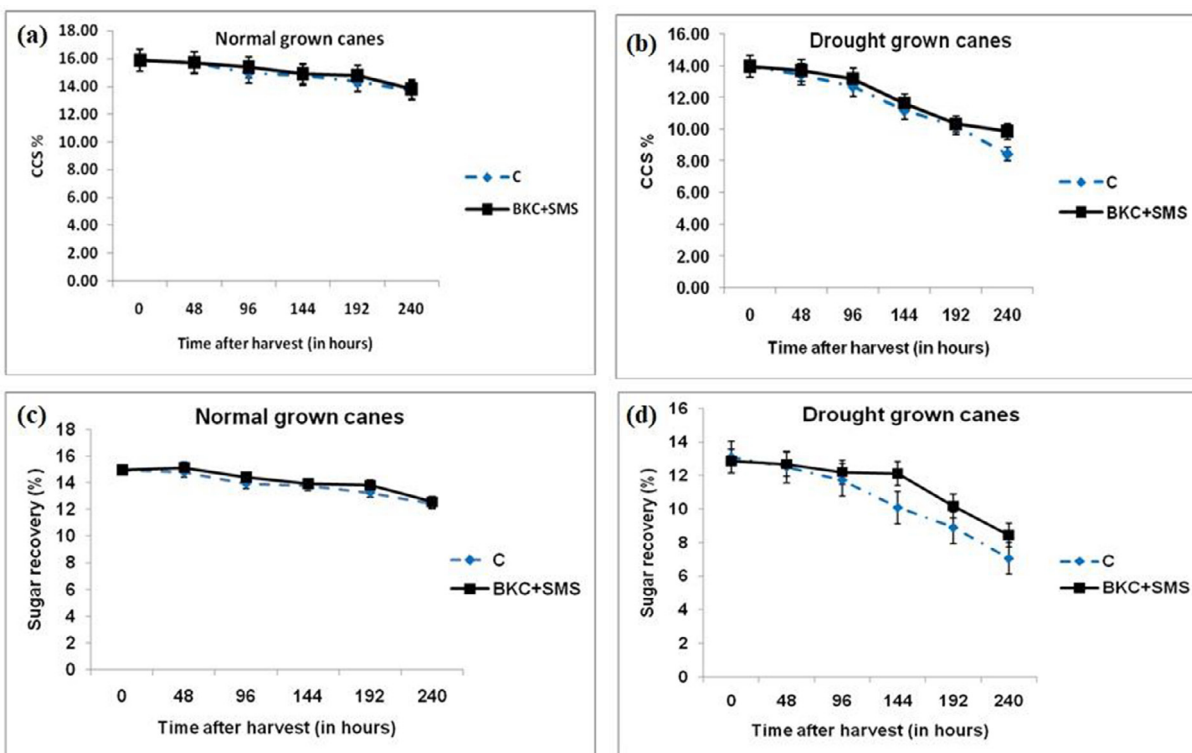
Similarly, Misra et al. (2016a) had also revealed that the quality of juice of drought affected canes was either superior or similar to the non-drought ones while the recovery % in respective canes was lower. Solomon et al. (2006) had also revealed that at field these losses varies in early, mid season and late crushing periods by 0.35, 1.0 and 1.32 units, respectively.

**Sugar recovery %:** In untreated normal grown sugarcane, sugar recovery % was 14.98 whereas it was 12.46 after 240 h of harvest. In BKC + SMS treated normal grown sugarcane, the sugar recovery % was 14.97 at 0 h and after 240 h of harvest, this gets decreased to

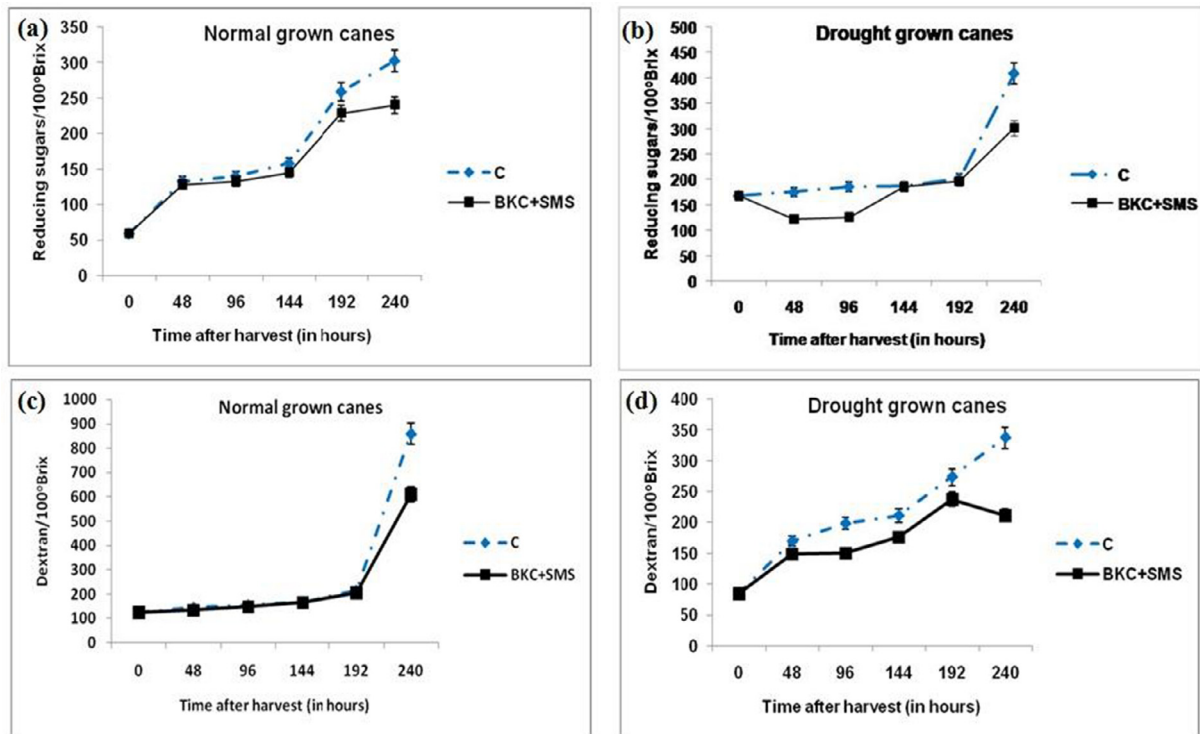
12.58. This showed that there was a decline of 2.51 units after 240 h of harvest in untreated normal canes while this decrease was relatively lesser in BKC + SMS treated normal canes (2.39 units) (Fig. 3c). Similarly, in untreated drought sugarcane harvested, the sugar recovery % was 13.12 and after 240 h of harvest, the sugar recovery % was decreased to 7.07. But in BKC + SMS treated drought sugarcane, the sugar recovery % was 12.88 at 0 h and after 240 h of harvest, this value decreased to 8.45. This indicated that there was a decline of 6.05 units after 240 h of harvest in untreated drought canes while this decrease was relatively less in BKC + SMS treated drought canes (4.43 units) (Fig. 3d). Comparative evaluation revealed that drought grown canes (1.620 units) had higher effectiveness of chemical formulation applied than the ones grown in normal condition (0.117 units). Statistical analysis showed that in sugar recovery %, there was non-statistical significance on hourly and treatment basis between normal untreated and normal treated canes ( $CD = 3.62$ ;  $CV = 15.72$ ;  $SE = \pm 1.23$ ). In drought untreated and drought treated canes, there was statistical significance on hourly basis and treatment basis ( $CD = 3.04$ ;  $CV = 16.88$ ;  $SE = \pm 1.03$ ).

**3.2. Impact of benzalkonium chloride (BKC) + Sodium metasilicate (SMS) chemical formulation spray on biochemical study (reducing sugars, dextran soluble acid invertase)**

**Reducing sugars/100°Brix:** In untreated normal grown sugarcane of March harvest, reducing sugars/100°Brix was recorded to be 59.33 at 0 h but after 240 h of harvest, this was increased to 302.40 whereas in BKC + SMS treated sugarcane, the value of reducing sugars/100°Brix was 59.33 at 0 h which increased after 240 h of harvest to 240.47. This indicated that there was an increase of 409.61% after 240 h of harvest in untreated normal grown canes but this decrease was relatively lesser in BKC + SMS



**Fig. 3.** Effect of juice quality parameters in sugarcane a & b: Loss in commercial cane sugars (CCS %) in normal and drought grown canes at an equal interval of 48 after harvest from 0 h till 240 h after harvest. The treatment tested was chemical formulation of benzalkonium chloride and sodium metasilicate (BKC + SMS) against untreated canes acting as Control (C); c & d: Loss in sugar recovery (%) in normal and drought grown canes at an equal interval of 48 after harvest from 0 h till 240 h after harvest wherein chemical formulation of benzalkonium chloride and sodium metasilicate (BKC + SMS) was tested against untreated canes acting as Control (C).



**Fig. 4.** Effect of biochemical parameters in post-harvest sugarcane a & b: Increase in reducing sugars in normal and drought grown canes at an equal interval of 48 after harvest from 0 h till 240 h after harvest. The treatment tested was chemical formulation of benzalkonium chloride and sodium metasilicate (BKC + SMS) against untreated canes acting as Control (C); c & d: Increasing pattern of dextran content in normal and drought grown canes at an equal interval of 48 after harvest from 0 h till 240 h after harvest wherein chemical formulation of benzalkonium chloride and sodium metasilicate (BKC + SMS) was tested against untreated canes acting as Control (C).

treated normal grown canes (305.10%) (Fig. 4a). Similarly, in untreated drought sugarcane harvested, the reducing sugars/100°Brix was 167.47 at 0 h after harvest and after 240 h of harvest, this value increased to 408.59 but in BKC + SMS treated drought canes, at 0 h of harvest, 167.47 value was recorded while after 240 h of harvest this was increased to 301.26. This indicated that there was a decrease of 143.97% after 240 h of harvest in untreated drought canes while this decrease was relatively lesser in BKC + SMS treated drought canes (79.88%) (Fig. 4b). On comparing the efficacy of the treatment, the drought affected treated canes (44.51%) showed relatively higher effect than the normal treated ones (25.50%) with respect to untreated canes. Statistical analysis revealed that in reducing sugars, there was statistical significant difference on hourly basis and treatment basis between normal untreated and normal treated canes (CD = 20.60; CV = 114.87; SE = ±7.38). In drought untreated and drought treated canes, there was statistical significant difference on hourly basis and treatment basis (CD = 12.45; CV = 67.98; SE = ±4.46).

Several studies conducted on cane deterioration had shown that reducing sugars acts as an important indicator in this process. The former also determines the extent up to which the former gets worsen (Uppal, 2003; Uppal and Sharma, 1997; Magdum et al., 1987; Ahmad and Khan, 1988; Gaur and Desai, 1988). High levels of reducing sugars during cane storage has been reported by several studies (Solomon et al., 1997, 2007). Misra et al. (2016a) had also illustrated rise in reducing sugars with increase in time after harvest.

**Dextran/100°Brix:** In untreated normal grown sugarcane, dextran/100°Brix was 124.67 and after 240 h of harvest, dextran/100°Brix value of 859.37 was observed but in BKC + SMS treated sugarcane, dextran/100°Brix was 124.67 at 0 h and after 240 h of harvest, this value was increased to 610.13. This showed that there was an increase of 589.31% after 240 h of harvest in untreated

canes but this increase was relatively lesser in BKC + SMS treated canes (389.39%) (Fig. 4c). Similarly, in untreated drought sugarcane harvested, dextran/100°Brix was 84.16 but after 240 h of harvest, this value increased to 337.43 but in BKC + SMS treated sugarcane, at 0 h of harvest, dextran/100°Brix was 84.16 while after 240 h of harvest, this increased to 211.45. This revealed that there was an increase of 300.93% after 240 h of harvest in untreated drought canes while this increase was relatively lesser in BKC + SMS treated drought canes (151.24%) (Fig. 4d). Comparative evaluation revealed that drought grown canes (49.74%) had higher effectiveness of chemical formulation applied than the ones grown in normal condition (33.92%). Statistical evaluation showed that in dextran, there was statistical significance on hourly basis as well as on treatment basis between normal untreated and normal treated canes (CD = 61.16; CV = 222.15; SE = ±21.92). In drought untreated and drought treated canes, there was statistical significance on hourly basis as well as on treatment basis (CD = 20.23; CV = 98.24; SE = ±7.25).

Dextran is an important aspect as it converts sucrose into dextran with the increase in cane staling. Studies have reported that amount of dextran in harvested stale cane juice increase rapidly. This increases with increase in activity of dextrasucrase. This dextrasucrase enzyme was secreted by *Leuconsotoc* bacteria (found in root rhizosphere) through extracellular form. The sucrose accumulated in cane gets converted into dextran through this enzyme as these microbes enter through the cut ends of harvested canes (Kin and Robyt, 1995; Misra et al., 2016b). Not only conversion of sucrose into dextran but also transfer of glucose molecule from sucrose for the formation of oligosaccharides such as leucrose and palatinose (Robyt, 1995; Robyt and Eklund, 1982) in the existence of carbohydrates like glucose and fructose, etc. (Robyt, 1995; Robyt and Eklund, 1982). It has been reported that dextrasucrase acts as a catalyst for sucrose hydrolysis. This makes it a possible criteria for

deterioration of cane after harvest (Eggleston and Legendre, 2000). In short, dextran is microbial product which is detrimental for sugarcane juice processing (Liu et al., 2019).

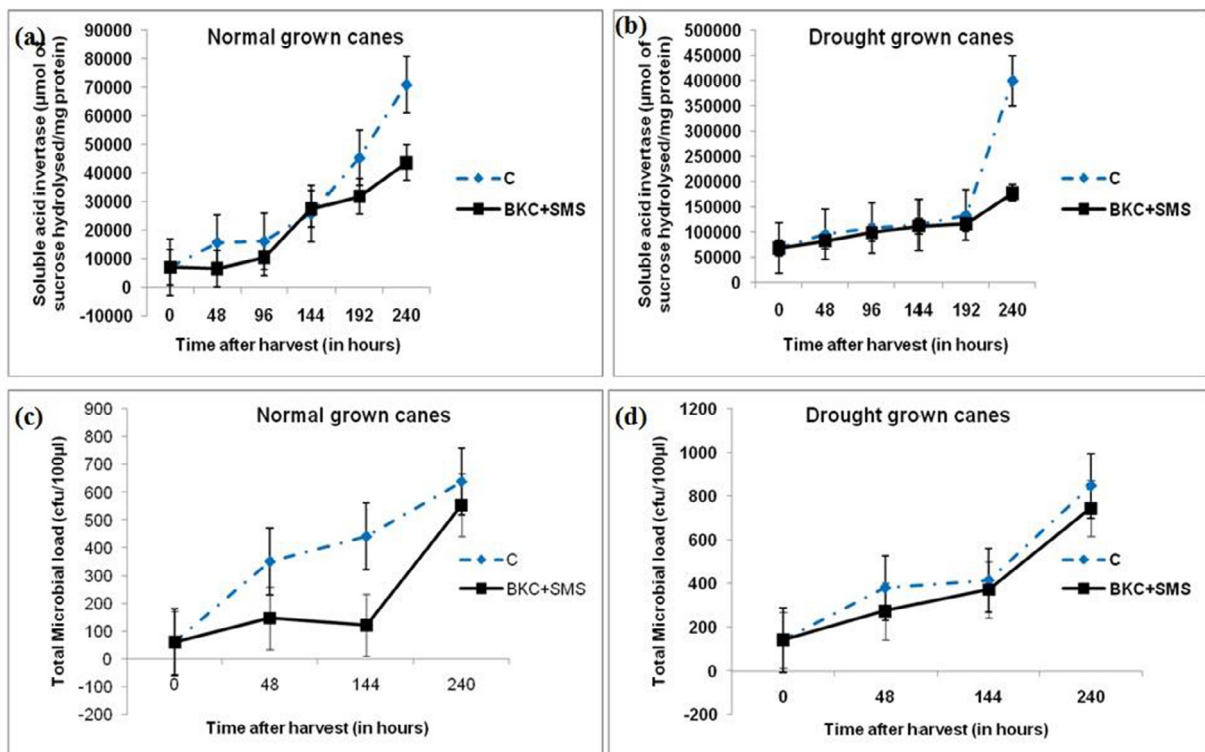
**Soluble acid invertase (SAI):** In untreated normal grown sugarcane, SAI was 7088.27 and after 240 h of harvest, SAI value of 71050.87 was observed but in BKC + SMS treated normal grown sugarcane, SAI was 7088.27 at 0 h and after 240 h of harvest, SAI value of 43703.62 was observed. This showed that there was an increase of 902.37% after 240 h of harvest in untreated normal grown canes while this increase was relatively lesser in BKC + SMS treated canes (516.56%) (Fig. 5a). Similarly, in untreated drought harvested sugarcane, the SAI was 67,500 but after 240 h of harvest, SAI value of 400,006 was observed. In BKC + SMS treated drought canes, SAI was 67,500 at 0 h and after 240 h of harvest, this value was increased to 177730.67. This demonstrated that there was an increase of 407.31% after 240 h of harvest in untreated drought canes whereas this increase was relatively lesser in BKC + SMS treated drought canes (163.30%) (Fig. 5b). On comparing the efficacy of the treatment, the drought affected treated canes (66.84%) showed relatively higher effect than the normal treated ones (42.75%) with respect to untreated canes. Statistical analysis illustrated that in SAI, there was statistical significance on hourly basis as well as on treatment basis between normal untreated and normal treated canes ( $CD = 5419.22$ ;  $CV = 203.09$ ;  $SE = \pm 1942.45$ ). In drought untreated and drought treated canes, there was statistical significance on hourly basis as well as on treatment basis no significant difference was seen ( $CD = 10595.59$ ;  $CV = 97.41$ ;  $SE = \pm 3797.87$ ).

Studies have shown that there is occurrence of inversion of sucrose leading to pol % decrease during post-harvest sugarcane storage (Rakkiyappan et al., 2009). Alexander (1973) had illustrated that invertase enzyme plays an important role in post-

harvest sucrose losses and once the cane is harvested presence of invertases causes cane tissue to lose its specificity. Invertases are involved prior and later cane is harvested where role in former is for sucrose accumulation but latter is for sucrose deterioration causing reduction in sugar yield and recovery (Shivalingamurthy et al., 2018). In normal canes, Solomon et al. (1990) showed that there was increase in both sorts of invertases (acidic and neutral) after 72 h of cane storage along with increasing invert sugars. Devi et al. (2019) had revealed that over expression of invertase and calmodulin functional proteins occurs in water stress condition as well as in recovery stage.

### 3.3. Effect of benzalkonium chloride (BKC) + Sodium metasilicate (SMS) chemical formulation spray on total microbial load:

In untreated normal grown canes, the total microbial load was 59.33 CfU/100  $\mu$ l at the time of harvest and after 240 h of harvest, the total microbial load was increased to 638.67 CfU/100  $\mu$ l. After usage of BKC + SMS over harvested normal grown sugarcane, total microbial load was 59.33 CfU/100  $\mu$ l at 0 h and after 240 h of harvest, the total microbial load value of 554.96 CfU/100  $\mu$ l was observed. This indicated that there was an increase of 976.47% after 240 h of harvest in untreated normal grown canes while this increase was relatively lesser in BKC + SMS treated canes (834.81%) (Fig. 5c). Similarly, in untreated drought harvested sugarcane, total microbial load was 140.33 CfU/100  $\mu$ l and after 240 h of harvest, total microbial load value of 848 CfU/100  $\mu$ l was observed, however, in BKC + SMS treated sugarcane, total microbial load was 141 CfU/100  $\mu$ l at 0 h and after 240 h of harvest, this value was increased to 746 CfU/100  $\mu$ l. This indicated that there was an increase of 504.28% after 240 h of harvest in untreated drought canes whereas this increase was relatively lesser in BKC + SMS



**Fig. 5.** Effect of soluble acid invertase and total microbial load in harvested sugarcane a & b: Increasing pattern of soluble acid invertase activity in normal and drought grown canes at an equal interval of 48 after harvest from 0 h till 240 h after harvest. The treatment tested was chemical formulation of benzalkonium chloride and sodium metasilicate (BKC + SMS) against untreated canes acting as Control (C); c & d: Increasing pattern of total microbial load (Cfu/100  $\mu$ l) in normal and drought grown canes at an equal interval of 48 after harvest from 0 h till 240 h after harvest wherein chemical formulation of benzalkonium chloride and sodium metasilicate (BKC + SMS) was tested against untreated canes acting as Control (C).



treated drought canes (429.07%) (Fig. 5d). Comparative evaluation revealed that drought grown canes (25.01%) had higher effectiveness of chemical formulation applied than the ones grown in normal condition (14.41%). Statistical evaluation showed that in total microbial load, there was statistical significance on hourly basis as well as on treatment basis between normal untreated and normal treated canes (CD = 83.99; CV = 138.56; SE = ±29.83). In drought untreated and drought treated canes, there was statistical significance on hourly basis as well as on treatment basis (CD = 95.29; CV = 113.01; SE = ±33.84).

Similar results as obtained in normal grown canes were also been observed by Krishnakumar et al. (2013) which showed that in juice microbial count was higher as the time after harvest increases. Frazier and Westhoff (1995) found out that many bacteria were responsible for the cane deterioration. The major ones were *Actinomyces*, *Enterobacter*, *Flavobacterium*, *Lactobacillus*, *Leuconostoc* and *Micrococcus*. Higher the number of microbes in juice higher is the juice viscosity as dextran formation occurs at a higher rate (Singh et al., 2006). Studies have shown that microbial invasion in harvested sugarcane causes formation of metabolic products such as organic acids (lactic acid, acetic acid, etc.) leading to sucrose inversion at industry level affecting sugar recovery (Rupa, 2013). To this *Leuconostoc* spp. plays important role in deteriorating sucrose content not only in harvested cane but even in standing canes possessing cracks (Misra et al., 2019). Solomon (2009) had showed that presence of yeast is commonly seen in juice which favors the production of acid and even ethanol while consuming the sucrose content.

## 5. Conclusion

Post-harvest sucrose loss in sugarcane is an important problem especially for sub-tropical region of India which contributes to low sugar recovery in mills. In the present running system of cane supply in Indian scenario, a delay of 3–5 days from cut-to-crush is a common phenomenon causing deterioration of sucrose content in sugarcane. It is known that abiotic stress exposed canes when harvested are more prone to faster sucrose deterioration (Solomon, 2014). There is a need for management of this crucial problem which evolved the idea of usage of chemical formulation (BKC + SMS) in harvested sugarcane grown under water stress condition. Based on the study, it was revealed that there were higher losses in post-harvest sugarcane under drought conditions in comparison to normal ones. Microbial infestation also contributed to increase in these losses in variety, Colk 94184, under drought condition. A clear picture of difference in sucrose losses after harvest in drought and normal grown canes in month of March has been depicted.

Sucrose deterioration was relatively minimized by the usage of chemical formulation leading to promising hold of it in future. Based on the results, our study illustrated that the sucrose content was reduced to 1.26 units along with reduction in commercial cane sugars of 1.42 units. This is due to reduction in increase in reducing sugars, dextran, soluble acid invertase and microbial infestation in drought canes after 240 h of harvest. Furthermore, this study helps in enhancing the sugar recovery at mill levels wherein mixed sorts of canes are crushed and processed into sugars. Post-harvest losses in sugarcane cause reduction in sugar recovery. Managing these losses at right way can help in increase the sugar recovery at 0.4–0.6 per cent at mills level and 1.5–2.0 per cent in respect to high quality of cane (Rupa, 2013). Monetary losses to farmers due to these losses have been reported to be around Rs 3500/day/100 tonnes (Solomon, 2000).

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