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Research

COMPARATIVE EFFECTS OF NEUTRAL AND ALKALINE SODIUM SALTS ON PHOTOSYNTHETIC PIGMENTS AND REDUCING SUGAR CONTENT IN COWPEA (VIGNA UNGUICULATA (L.) WALP.) CV. KONKAN SAFED

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Abstract

Soil salinity and alkalinity are major constraints for legume cultivation, particularly in coastal and semi-arid regions where sodium salts accumulate in the root zone. The present investigation examined the effect of neutral sodium chloride (NaCl; 10, 20 and 40 mM) and alkaline sodium bicarbonate ($NaHCO_3$; 6, 9 and 13 mM), along with neutral sodium sulphate (Na_2SO_4; 10, 20 and 30 mM), on photosynthetic pigments and reducing sugars in cowpea (*Vigna unguiculata* (L.) Walp.) cv. Konkan Safed at 21 days after sowing (DAS). Chlorophyll *a*, chlorophyll *b*, the chlorophyll *a*:*b* ratio and reducing sugars in shoot, root and leaves were estimated. NaCl caused only a mild reduction in chlorophyll content, whereas $NaHCO_3$ produced a pronounced decline, with chlorophyll *a* falling from 2.062 g/100 g fresh weight in the control to 0.733 g/100 g fresh weight at 13 mM. Na_2SO_4 increased chlorophyll *a* at 10 and 20 mM but reduced it sharply at 30 mM. Reducing sugars declined progressively in all plant parts under increasing NaCl stress. Alkaline $NaHCO_3$ maintained shoot sugars near control levels but reduced root and leaf sugars at the highest concentration. Na_2SO_4 caused an initial reduction in root sugars, followed by partial recovery at higher concentrations. The findings indicate that alkaline salinity is more damaging to the photosynthetic apparatus than neutral salinity, while soluble sugar accumulation may contribute to osmotic adjustment in cowpea under salt stress.

Keywords: Cowpea, chlorophyll, reducing sugars, NaCl, $NaHCO_3$, Na_2SO_4, salinity, alkalinity, *Vigna unguiculata*

1. Introduction

Cowpea (*Vigna unguiculata* (L.) Walp.) is an important pulse crop grown widely in tropical and subtropical regions. It provides inexpensive dietary protein, improves soil fertility through biological nitrogen fixation, and performs reasonably well under low-input farming conditions. However, its productivity is often limited by abiotic stresses, especially soil salinity and alkalinity.

Saline and sodic soils contain excess soluble salts that disturb water uptake, ion balance, enzyme activity and photosynthesis. Neutral salts such as sodium chloride (NaCl) and sodium sulphate (Na_2SO_4) mainly create osmotic stress and specific ion toxicity. In contrast, alkaline salts such as sodium bicarbonate ($NaHCO_3$) impose both salt stress and high rhizosphere pH,

which can interfere with nutrient availability and root functioning. Therefore, the response of crop plants to neutral and alkaline sodium salts may differ considerably.

Photosynthetic pigments are sensitive indicators of salt-induced injury. Chlorophyll degradation, reduced pigment synthesis and disturbance of chloroplast structure commonly occur when plants are exposed to excess sodium salts. A decline in chlorophyll content generally lowers the capacity of the plant to capture light energy and produce carbohydrates.

Reducing sugars, including glucose and fructose, serve as immediate energy sources and osmolytes. Under salt stress, soluble sugars may accumulate to maintain cell turgor and protect cellular structures. However, when photosynthesis is strongly inhibited, sugar reserves may decline because of reduced carbon assimilation and increased respiratory demand.

The Konkan region of Maharashtra experiences coastal salinity and variable soil pH conditions, making cowpea cv. Konkan Safed a suitable genotype for studying salt tolerance. The present work was therefore undertaken to compare the effects of neutral NaCl and Na_2SO_4 with alkaline $NaHCO_3$ on chlorophyll pigments and reducing sugars in cowpea seedlings.

2. Materials and Methods

2.1 Experimental material

Seeds of cowpea (*Vigna unguiculata* (L.) Walp.) cv. Konkan Safed were used for the experiment. Healthy and uniform seeds were selected and surface-sterilized before sowing.

2.2 Treatments

The experiment included one untreated control and nine salt treatments:

Salt type	Salt	Concentrations
Neutral salt	NaCl	10, 20 and 40 mM
Alkaline salt	$NaHCO_3$	6, 9 and 13 mM
Neutral salt	Na_2SO_4	10, 20 and 30 mM

Plants were grown under controlled conditions and sampled at 21 days after sowing (DAS).

2.3 Estimation of photosynthetic pigments

Fresh leaf tissue was used for chlorophyll estimation. Chlorophyll was extracted in an appropriate organic solvent, and absorbance was recorded spectrophotometrically. Chlorophyll *a*, chlorophyll *b* and total chlorophyll were calculated and expressed as g/100 g fresh weight. The chlorophyll *a*:*b* ratio was also determined.(Arnon (1949)

2.4 Estimation of reducing sugars

Reducing sugars were estimated separately in shoot, root and leaf samples. Fresh tissue was homogenized, extracted and reacted with a suitable colorimetric reagent. The developed colour was measured spectrophotometrically, and reducing sugar content was expressed as mg g^{-1} fresh weight. (Polin and Wu (1927)

2.5 Statistical presentation

Mean values for each treatment were tabulated and represented graphically. Percentage change over the control was calculated to compare the relative effects of neutral and alkaline sodium salts.

Chlorophyll (g/100g Fresh weight) (21 DAS)										
	Control		NaCl			NaHCO3			Na2SO4	
		10mM	20mM	40mM	6mM	9mM	13mM	10mM	20mM	30mM
Chl.a (21 DAS)	2.062	2.047	2.043	2.007	1.648	1.024	0.733	2.326	2.248	1.217
Chl.b(21 DAS)	2.067	2.042	2.040	2.036	0.949	0.697	0.512	1.401	0.932	0.906
a:b	0.997	1.002	1.001	0.985	1.736	1.469	1.431	1.660	2.412	1.343

Reducing Sugars(mg g^{-1} FW) (21 DAS)										
	Control		NaCl			NaHCO3			Na2SO4	
		10mM	20mM	40mM	6mM	9mM	13mM	10mM	20mM	30mM
Shoot(21 DAS)	7.12	6.9	6.67	6.14	6.61	6.52	6.18	6.78	6.41	6.24
Root(21 DAS)	1.97	1.43	1.03	0.88	1.91	1.69	1.2	1.08	1.55	1.63
Leaves(21 DAS)	1.88	1.67	1.33	1.10	1.88	1.78	1.17	1.56	1.34	1.29

3. Results and Observations

3.1 Chlorophyll pigments

The control plants recorded chlorophyll *a*, chlorophyll *b* and total chlorophyll values of 2.062, 2.067 and 4.129 g/100 g fresh weight, respectively. NaCl treatment caused a slight but gradual reduction in both pigments. At 40 mM NaCl, chlorophyll *a* decreased to 2.007 g/100 g fresh weight and chlorophyll *b* to 2.036 g/100 g fresh weight.

$NaHCO_3$ showed the strongest inhibitory effect. Chlorophyll *a* declined from 1.648 g/100 g fresh weight at 6 mM to 0.733 g/100 g fresh weight at 13 mM. Chlorophyll *b* showed a more severe reduction, decreasing from 0.949 to 0.512 g/100 g fresh weight over the same range. This indicates that alkaline stress affected chlorophyll *b* more strongly than chlorophyll *a*.

Na_2SO_4 produced a different response. At 10 and 20 mM, chlorophyll *a* increased to 2.326 and 2.248 g/100 g fresh weight, respectively, compared with the control. However, at 30 mM, chlorophyll *a* declined sharply to 1.217 g/100 g fresh weight. Chlorophyll *b* decreased progressively with increasing Na_2SO_4 concentration.

The chlorophyll *a*:*b* ratio increased under $NaHCO_3$ and Na_2SO_4 treatments, mainly because chlorophyll *b* declined more rapidly than chlorophyll *a*. The highest ratio, 2.412, was observed at 20 mM Na_2SO_4.

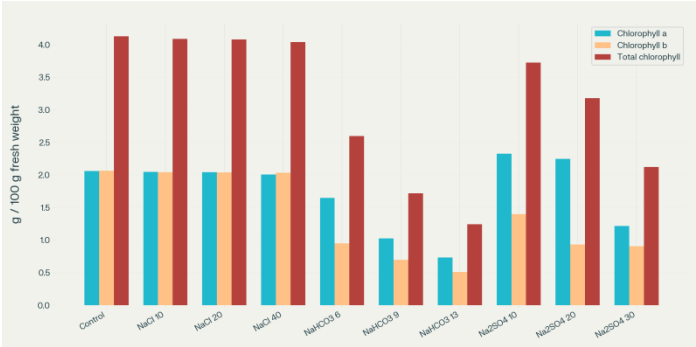


Figure 1. Effect of NaCl, $NaHCO_3$ and Na_2SO_4 on chlorophyll *a*, chlorophyll *b* and total chlorophyll in cowpea cv. Konkan Safed at 21 DAS.

3.2 Reducing sugars

In the control plants, reducing sugar content was 7.12 mg g^{-1} fresh weight in shoot, 1.97 mg g^{-1} fresh weight in root and 1.88 mg g^{-1} fresh weight in leaves. The shoot contained the largest sugar pool among the three organs.

Under NaCl stress, reducing sugars decreased in all plant parts with increasing concentration. In shoot, the value declined from 6.90 mg g^{-1} fresh weight at 10 mM to 6.14 mg g^{-1} fresh weight at 40 mM. Root sugars showed a stronger reduction, falling from 1.43 to 0.88 mg g^{-1} fresh weight. Leaf sugars also decreased from 1.67 to 1.10 mg g^{-1} fresh weight.

$NaHCO_3$ maintained shoot sugars relatively close to the control level. At 6 and 9 mM, shoot sugar values were 6.61 and 6.52 mg g^{-1} fresh weight, respectively, while at 13 mM the value decreased to 6.18 mg g^{-1} fresh weight. Root sugars declined from 1.91 mg g^{-1} fresh weight at 6 mM to 1.20 mg g^{-1} fresh weight at 13 mM. Leaf sugars decreased from 1.88 to 1.17 mg g^{-1} fresh weight.

Na_2SO_4 caused an initial decline in root sugars at 10 mM, followed by partial recovery at 20 and 30 mM. Shoot sugars decreased gradually from 6.78 to 6.24 mg g^{-1} fresh weight. Leaf sugars declined from 1.56 mg g^{-1} fresh weight at 10 mM to 1.29 mg g^{-1} fresh weight at 30 mM.

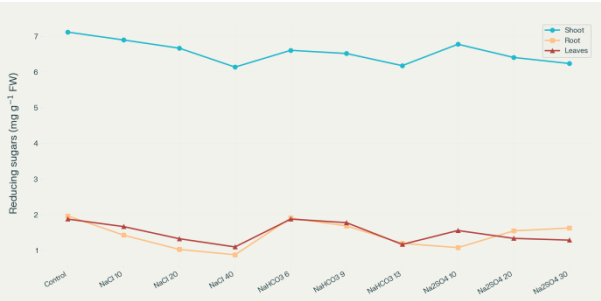


Figure 2. Effect of NaCl, $NaHCO_3$ and Na_2SO_4 on reducing sugar content in shoot, root and leaves of cowpea cv. Konkan Safed at 21 DAS.

3.3 Major observations

- NaCl caused a mild reduction in chlorophyll pigments and a steady decline in reducing sugars.

- $NaHCO_3$ was the most damaging treatment for chlorophyll content, especially at 13 mM.
- Chlorophyll *b* was more sensitive to alkaline stress than chlorophyll *a*.
- Na_2SO_4 at 10 and 20 mM stimulated chlorophyll *a*, but 30 mM caused a sharp decline.
- Shoot tissues retained higher reducing sugar levels than roots and leaves across all treatments.
- Root sugars were highly sensitive to NaCl, suggesting that root carbon metabolism is strongly affected by chloride salinity.

4. Discussion

The reduction in chlorophyll content under NaCl and $NaHCO_3$ treatments can be attributed to salt-induced inhibition of chlorophyll biosynthesis, increased pigment degradation and disturbance of chloroplast membranes. Sodium accumulation may also reduce magnesium uptake or availability, thereby affecting the stability of the chlorophyll molecule.

The stronger effect of $NaHCO_3$ compared with NaCl indicates that alkalinity imposes additional stress beyond sodium toxicity. High bicarbonate concentration increases rhizosphere pH, which can reduce the availability of essential nutrients and impair root activity (Sairam, R. K., & Tyagi, A. (2004). This may explain the severe loss of chlorophyll observed at 13 mM $NaHCO_3$.

The increase in chlorophyll *a* at lower Na_2SO_4 concentrations may reflect a mild stimulatory response, possibly related to sulphur availability. Sulphur is required for amino acid and protein synthesis, and a limited supply may support early vegetative growth. However, at 30 mM, the harmful effects of excess sodium and sulphate appear to dominate, resulting in pigment loss.

The decline in reducing sugars under NaCl suggests reduced photosynthetic carbon assimilation and increased utilization of carbohydrates for respiratory and stress-response processes. Roots showed a greater reduction than shoots, possibly because roots are the first organ exposed to salt and may consume sugars rapidly for ion regulation and maintenance.

The relative stability of shoot sugars under $NaHCO_3$ may indicate partial osmotic adjustment. Soluble sugars can help maintain cellular water status when external water potential becomes more negative (Chaves, M. M., Flexas, J., & Pinheiro, C. (2009).. However, the decline in root and leaf sugars at higher $NaHCO_3$ levels suggests that this protective mechanism becomes insufficient under severe alkaline stress.

Overall, the results show that cowpea cv. Konkan Safed is more sensitive to alkaline sodium bicarbonate than to neutral sodium chloride. Moderate Na_2SO_4 appears less harmful initially, but high concentration adversely affects both pigments and carbohydrate metabolism.

5. Conclusion

Neutral and alkaline sodium salts differentially affected photosynthetic pigments and reducing sugars in cowpea cv. Konkan Safed. NaCl caused gradual but moderate reductions in chlorophyll and sugars, while $NaHCO_3$ produced the strongest inhibition of chlorophyll synthesis, particularly chlorophyll *b*. Na_2SO_4 showed a mild stimulatory effect on chlorophyll *a* at lower concentrations but became toxic at 30 mM.

Reducing sugars declined in all plant parts under NaCl stress, whereas $NaHCO_3$ and Na_2SO_4 showed organ-specific responses. The maintenance of shoot sugars under alkaline stress may

represent an osmotic adjustment mechanism, but it was not sufficient to prevent chlorophyll loss. These findings suggest that alkaline salinity is a more serious constraint for cowpea cultivation than neutral salinity. Selection and breeding of cowpea genotypes with stable chlorophyll content and efficient sugar metabolism may improve tolerance to saline-alkaline soils.

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