

Response of OPV Corn (Zea Mays) to Antitranspirants (Chitosan) Under Drought Stress

SHARLENE D. ANDAYA

Mindoro State University, Alcate, Victoria, Oriental Mindoro

Abstract- Chitosan is gaining recognition in crop science as a natural antitranspirant that improves plant water-use efficiency and enhances resilience under drought stress. This study investigated the effects of chitosan derived from golden apple snail shells on the growth, physiological response, and yield performance of glutinous open-pollinated variety (OPV) corn (*Zea mays*) under drought conditions. Conducted from February 23 to April 29, 2025, in Macatoc, Victoria, Oriental Mindoro, the experiment followed a 3×4 factorial design using a Randomized Complete Block Design, with Factor A being water stress intervals (regular, 15 days, and 25 days) and Factor B being chitosan levels (0, 50, 100, and 150 ml/L). Results showed that the first factor (water stress interval) had a significant effect ($p < 0.05$) on key growth traits such as plant height, number of leaves, leaf area, and fresh and dry biomass, with regular watering (A1) producing superior values compared to 15-day (A2) and 25-day (A3) intervals. However, yield components like corn ear diameter, length, and weight showed comparable results between A1 and A2, suggesting moderate water stress did not drastically affect reproductive traits. The second factor (chitosan level) significantly influenced all parameters, with 100 ml/L (B3) producing the best performance in plant height, leaf area, number of leaves, biomass, corn ear traits, Relative Water Content (RWC), and Excised Leaf Water Retention (ELWR). The 150 ml/L treatment (B4) also improved traits but with diminishing gains or slight physiological suppression. The interaction between water stress intervals and chitosan levels was significant for plant height, number of leaves, leaf area, and RWC, especially at 6 and 8 weeks after planting. Notably, the combination of 100 ml/L chitosan and 15-day water stress interval (A2B3) showed performance comparable to the regularly watered treatment, indicating chitosan's mitigating role under moderate drought. These findings support the application of chitosan at optimal concentrations as an eco-friendly, biodegradable strategy to enhance maize performance under water-limited conditions, reinforcing its value in climate-smart agriculture.

Keywords: Excised Leaf Water Retention, Growth performance, OPV Corn, Relative water content, Yield parameters

I. INTRODUCTION

Corn plant (*Zea mays*), is consider one of the staple food and consider as the most important crop in the Philippines. According to (Cerpacio, 2004) the white maize is the most important substitute staple in periods were people in rural areas suffer from rice shortage, (Cerpacio, 2004). Corn plant consider one of the most important grass family but unfortunately due to climate change, land suitable for cultivation are significantly reduce . It also, requires 380 to 550 mm of water to obtain the maximum production in maize, (Almeida,2018).

Limitation in crop production sometimes is due to different environmental stress, main of this environmental factors are the biotic and abiotic stresses. Biotic stress factors include a variety of organisms that may cause diseases, infections, and plant damage, these stress also could lead to the reduction in yield. On the other hand, abiotic stresses are stress that caused by non-living a natural events, such as temperature, drought, flooding. The severity of this abiotic stresses is the result of the ongoing climate change that are experienced all over the world. This is causing many crops to be exposed to conditions where the temperature which is result to reduction of production (Kociecka, 2023).

One of the solutions that many of the scientist and researcher are studied now a days was the use of antitranspirants, the antitranspirants are products that help to reduce transpiration process in plants. There are three basic groups of antitranspirant, first was film-forming, stomata-closing or metabolic and last was the reflective type. Transpiration loss of water from the plants from the stomata of the leaves. When there's to much transpiration happen in the plants without enough water to absorb, growth of the plant will affect.

The stomata closing or metabolic antitranspirant is one of the processing solution to mitigate the effect of the transpiration. According to (Katiyar et al., 2015) antitranspirants chitosan considered a biostimulant, can stimulate physiological responses to water deficit tolerance. It is used in agriculture as a protection of plant for proper growth because water is important in making the own food of a plants, Pongprayoon et.al, 2020.

Chitosan is derived from chitin, one of the polysaccharides which are one of the main constituents of the shells of the crustacean animals from (crabs and shrimp), molluscs (clams and snail) and also from insects (Islam et al., 2017). As the world experiencing global warming because of the product that is harmful to our nature, chitosan as one of naturally non-toxic and biodegradable solution to avoid the drastic effect of global warming.

Golden apple snail (*Pomacea canaliculata*) one of crustacean animals has the potential source of chitin properties and could derived to chitosan. We all know that golden apple snail is a notorious pest in the rice fields of the Philippines. Production loss will increase to 98% when the golden apple snail are present during vegetative stage. DA PhilRice, (2019). This antitranspirant chitosan from golden apple snail has the potential to turn problem to a solution, that a notorious problem in agriculture maybe the solution also to agriculture. As cited of (Larasati et. al., 2023), golden apple snail has 82.33% deacetylation degree.

II. METHODOLOGY

The study was laid out in 3x4 experiment in Randomized Complete Block Design. Among the factor observed were water stress interval (Factor A) and application of antitranspirant (chitosan) at different levels (Factor B). Each treatment were replicated three (3) times. A total of 406 were planted in the experimental area, 360 sample plants and 46 boarder plants.

Factor A: Water stress interval (days)

- A1 – Regular watering
- A2 – 15 days
- A3 – 25 days

Factor B: Chitosan level (ml/L)

- B1 – control
- B2 – 50
- B3 – 100
- B4 – 150

Treatment Combinations

- A1B1: Regular watering + Control
- A1B2: Regular watering + 50 ml chitosan /liter of water
- A1B3: Regular watering + 100 ml chitosan /liter of water
- A1B4: Regular watering + 150 ml chitosan /liter of water
- A2B1: 15 days (water stress interval) + Control
- A2B2: 15 days (water stress interval) + 50 ml chitosan /liter of water
- A2B3: 15 days (water stress interval) + 100 ml chitosan /liter of water
- A2B4: 15 days (water stress interval) + 150 ml chitosan /liter of water
- A3B1 : 25 days (water stress interval) + Control
- A3B2 : 25 days (water stress interval) + 50 ml chitosan /liter of water
- A3B3 : 25 days (water stress interval) + 100 ml chitosan /liter of water
- A3B4: 25 days (water stress interval) + 150 ml chitosan /liter of water

An experimental modified greenhouse covering 151.88 m² was established using materials such as UV-stabilized plastic, agricultural netting, and bamboo.

In the extraction of chitosan, the researcher used golden apple snail shell and custard apple leaves as a main ingredient to extract chitosan and apply it to corn plant.

Golden apple snail was sun dried for 2 days at 10:00 am to 3:00 pm and crush into 0.25 mm to 0.5 mm in size while the 16 pieces of Atis leaves was cut into small strips (1 inch) and was boil to 400 ml of distilled water until half the original volume evaporate. After this, the golden apple snail and the 200 ml extraction from the Atis leaves undergo fermentation for 21 days. Leaves of atis contain acetogenins which is important on dechitinization activity to produce chitosan (Larasati et. al (2023). The whole process of

extracting chitosan was based on the study conducted by Kimi and Hamdi (2023); NTU Singapore (2020) and Gopal et. al (2019).

Data was gather from ten (10) sample plants from each plot, and the data to be gather are as follows: growth parameters (plant height (cm), stem diameter, number of leaves, leaf area, fresh and dry biomass); yield parameters (number of corn ear, diameter of corn ear (mm), length of corn ear (cm), corn ear weight , yield per plot, yield per hectare) and physiological response (relative water content (%), excised leaf water retention (%)).

Data collected from the experiment were subjected to Analysis of Variance (ANOVA) to determine the significance of the main effects of water stress interval and chitosan level, as well as their interaction effects on the measured response variables.

All data were analyzed using SAS statistical software (Version 9.4), which is widely used for robust and reliable analysis of experimental data in agricultural research. Prior to conducting ANOVA, data were checked for assumptions of normality and homogeneity of variance using residual diagnostics and Levene's test. When significant differences ($p < 0.05$ or $p < 0.01$) among treatment means were detected through ANOVA, pairwise comparisons

were made using Scheffé's post hoc test, which is suitable for making multiple comparisons in factorial designs while controlling the familywise error rate (Scheffé, 1953).

III. RESULT AND DISCUSSION

Plant Height (cm)

The study determine the impact of different water stress intervals on corn plant height at five growth stages (7 DAP to 8 WAP). Treatments included regular watering (A1), 15 day interval (A2), and 25 day interval (A3). Results showed that water stress significantly reduced plant height at later stages, particularly at 6 and 8 weeks after planting (WAP). By 8 weeks after planting (WAP), A1 plants reached the tallest average height (224.07 cm), significantly higher than A2 (205.68 cm) and A3 (196.92 cm). The height reduction in A2 and A3 was due to limited turgor pressure, cell elongation, nutrient uptake, and photosynthesis under water stress, especially during critical stages like stem elongation and tasseling.

These findings align with previous research (Li et al., 2020; Wang et al., 2019; Hassnain et al., 2019; Mondal et al., 2013), reinforcing the importance of consistent irrigation for optimal corn growth and development.

Table 1 Plant height of OPV corn as affected by Water Stress Interval

Water Stress Interval	Plant height (cm)				
	7DAP (0.0781)	2WAP (0.0367)	4WAP (0.0919)	6WAP (0.0045)	8WAP (0.0002)
A1	15.31 ^a	44.93 ^a	123.31 ^a	197.73 ^a	224.07 ^a
A2	15.19 ^a	42.63 ^{ab}	116.18 ^a	182.57 ^{ab}	205.68 ^b
A3	14.39 ^a	41.18 ^b	113.84 ^a	173.74 ^b	196.92 ^b

Legend: Means within the column with the same superscript were not significantly different ($p > 0.05$); A1 - Regular Watering; A2-15 days; A3- 25 days, DAP- Days after planting; WAP – weeks after planting

The study evaluated the effects of different chitosan concentrations (B1 -B4) on corn plant height under

greenhouse drought conditions. The 100 ml/L treatment (B3) consistently resulted in the tallest plants, especially at 6 and 8 weeks after planting (197.57 cm and 229.57 cm, respectively). While 150 ml/L (B4) showed early growth benefits, 100 ml/L emerged as the optimal dose for promoting plant height under water-limited conditions.

Chitosan's growth promoting effects are related to its ability to improve stomatal regulation, enhance antioxidant activity, and activate stress responsive genes. However, higher concentrations (150 ml/L) may inhibit gas exchange and photosynthesis, reducing effectiveness.

These findings support prior research (Mondal et al., 2013; Boonlertnirun et al., 2011), affirming that moderate chitosan application improves growth and drought resilience in cereal crops like corn.

Table 2 Plant height of OPV corn as affected by Chitosan level (ml/L) as Antitranspirant

Chitosan as Antitranspirant	Plant Height (cm)				
	7DAP (0.0077)	2WAP (0.0063)	4WAP (0.0192)	6WAP (0.0239)	8WAP (0.0001)
B1	15.48 ^{ab}	39.54 ^b	108.35 ^b	172.29 ^b	186.12 ^c
B2	14.45 ^{ab}	42.30 ^{ab}	116.54 ^{ab}	183.24 ^{ab}	205.92 ^b
B3	15.76 ^a	44.60 ^a	122.20 ^a	197.57 ^a	229.57 ^a
B4	14.17 ^b	45.21 ^a	124.00 ^a	185.61 ^{ab}	213.94 ^{ab}

Legend: Means within the column with the same superscript were not significantly different ($p < 0.01$);

B1- Control; B2- 50ml; B3- 100 ml; B4- 150ml, Days After Planting; WAP – weeks after planting.

The study assessed the interaction between water stress intervals and chitosan concentrations on corn plant height from 2 to 8 WAP.

The tallest plants were consistently observed in A1B3 (regular watering + 100 ml/L chitosan) and A2B3 (15-

day interval + 100 ml/L chitosan), reaching 251.63 cm and 229.93 cm at 8 WAP. This indicates that 100 ml/L chitosan effectively enhances growth, particularly under moderate drought. In contrast, severe stress (A3) limited plant height regardless of chitosan level, showing that chitosan's effectiveness declines under extreme drought.

These results reinforce chitosan's role in enhancing drought tolerance through mechanisms such as stomatal control and root development. However, 150 ml/L may lead to overstimulation and reduced photosynthesis, especially under stress.

Table 3 Plant Height (cm) of OPV corn as affected by the Interaction Between Water Stress Interval and Chitosan level (ml/L) as Antitranspirant

Treatments Combinations	Plant Height (cm)				
	7DAP (P value = 0.0075)	2WAP (P value = 0.6320)	4WAP (P value = 0.8670)	6WAP (P value = 0.7788)	8WAP (P value = 0.5186)
A1B1	16.72±0.78	42.63±2.66	114.49±7.24	186.13±26.40	197.98±14.31
A1B2	14.02±0.45	44.73±6.18	124.20±30.98	197.60±37.81	214.33±8.52
A1B3	16.63±1.10	45.83±1.62	125.50±7.34	206.70±29.35	251.63±19.42
A1B4	13.88±1.48	46.50±6.15	129.03±18.22	200.47±32.55	232.33±27.89
A2B1	16.00±1.54	38.37±2.74	109.10±21.54	170.53±7.86	180.50±6.32
A2B2	15.48±0.10	39.33±2.61	110.07±7.01	175.03±4.20	203.77±6.41
A2B3	15.95±1.15	44.63±2.25	125.00±11.36	205.97±25.65	229.93±24.42
A2B4	13.34±1.08	42.40±0.92	120.53±4.37	178.73±4.22	208.50±1.80
A3B1	13.73±0.70	37.63±3.33	101.47±17.42	160.20±11.63	179.87±7.95

A3B2	13.85±2.22	42.83±6.63	115.37±12.33	177.10±2.93	199.67±1.26
A3B3	14.69±0.71	43.33±1.07	116.10±9.45	180.03±16.83	207.13±22.43
A3B4	15.28±1.48	46.73±5.08	122.43±13.44	177.63±5.47	201.00±5.90

Legend: A1B1: Regular watering + Control; A1B2 : Regular watering + 50 ml chitosan /liter of water; A1B3 : Regular watering + 100 ml chitosan /liter of water; A1B4: Regular watering + 150 ml chitosan /liter of water; A2B1: 15 days (water stress interval) + Control; A2B2: 15 days (water stress interval) + 50 ml chitosan /liter of water A2B3: 15 days (water stress interval) + 100 ml chitosan /liter of water A2B4: 15 days (water stress interval) + 150 ml chitosan /liter of water ; A3B1 : 25 days (water stress interval) + Control ; A3B2 : 25 days (water stress interval) + 50 ml chitosan /liter of water ; A3B3 : 25 days (water stress interval) + 100 ml chitosan /liter of water; A3B4: 25 days (water stress interval) + 150 ml chitosan /liter of water ,Days After Planting,

Number of Leaves

Plants under (A1)- regular watering produced the most leaves, while those under (A2)- 15 day and especially (A3)- 25 day intervals had reduced leaf develop. The decline in leaf number under water stress is linked to reduced turgor pressure, impaired cell division, and physiological stress, as supported by earlier studies (Riaz et al., 2013; Farooq et al., 2009; Flexas & Medrano, 2002; Anjum et al., 2011).

Frequent irrigation is essential for optimal leaf formation and vegetative growth in corn. Extended drought intervals suppress leaf development, highlighting the importance of timely watering during early and mid vegetative stages to maintain productivity.

Table 4 Number of Leaves of OPV corn as affected by Water Stress Interval

Water Stress Interval	Number of Leaves				
	7DAP (0.1726)	2WAP (0.6717)	4WAP (<.0001)	6WAP (<.0001)	8WAP (0018)
A1	3.38 ^a	5.87 ^a	8.92 ^a	11.04 ^a	9.10 ^a
A2	3.33 ^a	6.02 ^a	8.63 ^b	10.53 ^b	8.78 ^{ab}
A3	3.44 ^a	5.88 ^a	8.45 ^c	10.21 ^c	8.38 ^b

Legend: Means within the column with the same superscript were not significantly different ($p>0.05$); A1 - Regular Watering; A2-15 days; A3- 25 days, DAP- Days after planting

The study found that while leaf number differences were minimal at 7 DAP, by 4 weeks after planting, the highest leaf production was observed in B4 (150 ml/L chitosan), followed by B3 (100 ml/L), B2 (50 ml/L), and the control (B1). This ranking persisted through 6 and 8 weeks after planting, demonstrating a dose dependent effect of chitosan on leaf development.

The improved vegetative growth is attributed to chitosan's role as an antitranspirant and biostimulant, enhancing photosynthesis, stress tolerance, and antioxidant defense, as supported by Khan et al. (2002), Iriti & Faoro (2009), Mondal et al. (2012), and Sharif et al. (2018).

Table 5 Number of Leaves of OPV corn as affected by Chitosan Level (ml/L) as Antitranspirant

Chitosan as Antitranspirant	Number of Leaves				
	7DAP (0.0177)	2WAP (0.0334)	4WAP (<.001)	6WAP (.0001)	8WAP (0.0030)

B1	3.48 ^a	5.50 ^b	8.08 ^d	10.10 ^c	8.44 ^b	WAP), followed closely by A1B3. Under
B2	3.39 ^{ab}	5.99 ^{ab}	8.59 ^c	10.53 ^b	8.53 ^b	
B3	3.24 ^b	6.07 ^{ab}	8.86 ^b	10.92 ^a	9.23 ^a	
B4	3.42 ^{ab}	6.12 ^a	9.14 ^a	10.81 ^a	8.81 ^{ab}	

Legend: Means within the column with the same superscript were not significantly different ($p < 0.01$); B1- Control; B2- 50ml; B3- 100 ml; B4- 150ml

Interaction effects between water stress and chitosan application on corn leaf development became statistically significant only at 4 WAP ($p = 0.0025$) and 6 WAP ($p = 0.0003$). No significant differences were observed at 7 DAP, 2 WAP, or 8 WAP.

The most leaves were produced under regular watering (A1) combined with 100 - 150 ml/L chitosan, particularly A1B4 (9.33 leaves at 4 WAP; 11.07 at 6

moderate drought (A2), leaf production also improved with higher chitosan concentrations (A2B3, A2B4), indicating partial mitigation of water stress. But, under severe drought (A3), leaf numbers remained low across all chitosan levels, highlighting the limited compensatory effect under extreme conditions.

Chitosan at 100 - 150 ml/L enhances leaf development most effectively under adequate to moderately limited water conditions, proving valuable for drought-resilient corn management strategies.

Table 6 Number of Leaves of OPV corn as affected by the Interaction between Water Stress Interval and Chitosan level (ml/L) as Antitranspirant

Treatments Combinations	Number of Leaves				
	7DAP (P value = 0.0906)	2WAP (P value = 0.3942)	4WAP (P value = 0.0025)	6WAP (P value = 0.0003)	8WAP (P value = 0.9979)
A1B1	3.47±0.06	4.97±1.62	8.57±0.12	10.83±0.06	8.90±0.36
A1B2	3.20±0.10	6.10±0.00	8.77±0.06	11.03±0.06	8.83±0.55
A1B3	3.33±0.06	6.17±0.06	9.00±0.10	11.23±0.15	9.53±0.06
A1B4	3.53±0.15	6.23±0.06	9.33±0.12	11.07±0.06	9.13±0.29
A2B1	3.43±0.12	5.83±0.06	7.90±0.17	9.97±0.06	8.43±0.57
A2B2	3.47±0.06	6.00±0.10	8.60±0.10	10.50±0.00	8.57±0.40
A2B3	3.13±0.25	6.10±0.10	8.87±0.12	10.87±0.12	9.30±1.04
A2B4	3.27±0.15	6.13±0.15	9.17±0.06	10.77±0.12	8.83±0.29
A3B1	3.53±0.15	5.70±0.00	7.77±0.15	9.50±0.10	8.00±0.26
A3B2	3.50±0.17	5.87±0.12	8.40±0.20	10.07±0.25	8.20±0.72
A3B3	3.27±0.15	5.93±0.21	8.70±0.10	10.67±0.12	8.87±0.40
A3B4	3.47±0.15	6.00±0.20	8.93±0.15	10.60±0.26	8.47±0.25

Legend: A1B1: Regular watering + Control; A1B2 : Regular watering + 50 ml chitosan /liter of water; A1B3 : Regular watering + 100 ml chitosan /liter of water; A1B4: Regular watering + 150 ml chitosan /liter of water; A2B1: 15 days (water stress interval) + Control; A2B2: 15 days (water stress interval) + 50 ml chitosan /liter of water A2B3: 15 days (water stress interval) + 100 ml chitosan /liter of water A2B4: 15 days (water stress interval)

+ 150 ml chitosan /liter of water ; A3B1 : 25 days (water stress interval) + Control ; A3B2 : 25 days (water stress interval) + 50 ml chitosan /liter of water ; A3B3 : 25 days (water stress interval) + 100 ml chitosan /liter of water; A3B4: 25 days (water stress interval) + 150 ml chitosan /liter of water; DAP- Days After Planting, WAP – weeks after planting

Stem Diameter (mm)

The study revealed that water stress intervals significantly affected corn stem diameter ($p < 0.0001$). Plants under regular watering (A1) had the thickest stems (13.30 mm), significantly larger than those under 15 day (A2 - 11.92 mm) and 25 day (A3 - 11.54 mm) intervals. While A2 and A3 did not differ significantly from each other, both showed clear reductions compared to A1.

Reduced stem thickness under drought reflects limited turgor pressure, compromising plant strength and transport capacity. These findings align with studies by Farooq et al. (2009), Hsiao et al. (2000), and Zhang et al. (2018).

Table 7 Stem Diameter (mm) of OPV corn as affected by Water Stress Interval

Water Stress Interval	Stem Diameter (mm) (<0.0001)
A1	13.30 ^a
A3	11.54 ^b

Legend: Means within the column with the same superscript were not significantly different ($p > 0.05$); A1 - Regular Watering; A2-15 days; A3- 25 days

Chitosan application significantly affected corn stem diameter ($p = 0.0059$), as detailed in Table 8. The highest concentration (B4- 150 ml/L) produced the thickest stems (12.93 mm), significantly more than the control (B1 - 11.47 mm). Lower concentrations (B2- 12.08 mm; B3- 12.52 mm) also improved stem diameter, indicating a positive dose dependent effect.

This improvement is linked to chitosan's biostimulant properties, enhancing metabolism, vascular development, and cell wall fortification. Studies by Khan et al. (2002), Iriti & Faoro (2009), and Sharif et al. (2018) support these findings.

Chitosan, particularly at 150 ml/L, enhances corn stem thickness, promoting better mechanical strength and

plant vigor in both well-watered and drought conditions.

Table 8 Stem Diameter of OPV corn as affected by Chitosan level (ml/L) as Antitranspirant

Chitosan Level as Antitranspirant	Stem Diameter (mm) (0.0059)
B1	11.47 ^b
B2	12.08 ^{ab}
B3	12.52 ^{ab}
B4	12.93 ^a

Legend: Means within the column with the same superscript were not significantly different ($p < 0.01$); B1- Control; B2- 50ml; B3- 100 ml; B4- 150ml

Although the interaction between water stress intervals and chitosan application on corn stem diameter was not statistically significant ($p = 0.8096$), Table 9 reveals important trends. Under regular watering (A1), stem diameter was highest across all chitosan levels, especially with 150 ml/L chitosan (A1B4 - 13.89 mm). Even without chitosan, well-watered plants maintained thick stems (A1B1 - 12.97 mm).

Under moderate drought (A2), stem thickness declined in untreated plants (A2B1- 11.07 mm) but improved with chitosan, peaking at A2B4- 12.59 mm. Under severe drought (A3), the lowest stem diameter was in A3B1- 10.38 mm, while A3B4- 12.31 mm showed remarkable improvement, nearing values seen in well-watered plants with lower chitosan levels.

These results indicate that chitosan enhances stem development under stress, supporting its role in improving water retention, cell wall integrity, and hormonal balance, as corroborated by Abdel-Aziz et al. (2006), Guan et al. (2009).

Table 9 Stem Diameter (mm) of OPV corn as affected by the Interaction between Water Stress Interval and Chitosan level (ml/L) as Antitranspirant

Treatment Combinations	Stem Diameter (mm)
	P value=0.8096
A1B1	12.97±1.11
A1B2	13.11±1.07
A1B3	13.22±1.50
A1B4	13.89±1.66
A2B1	11.07±0.77
A2B2	11.55±1.49
A2B3	12.44±1.00
A2B4	12.59±0.70
A3B1	10.38±0.01
A3B2	11.56±1.04
A3B3	11.90±1.44
A3B4	12.31±1.72

Legend: A1B1 - Regular watering + Control; A1B2 - Regular watering + 50 ml chitosan /liter of water; A1B3 - Regular watering + 100 ml chitosan /liter of water; A1B4: Regular watering + 150 ml chitosan /liter of water; A2B1: 15 days (water stress interval) + Control; A2B2 - 15 days (water stress interval) + 50 ml chitosan /liter of water; A2B3 - 5 days (water stress interval) + 100 ml chitosan /liter of water; A2B4 - 15 days (water stress interval) + 150 ml chitosan /liter of water; A3B1 - 25 days (water stress interval) + Control ; A3B2 - 25 days (water stress interval) + 50 ml chitosan /liter of water; A3B3 - 25 days (water stress interval) + 100 ml chitosan /liter of water; A3B4 - 25 days (water stress interval) + 150 ml chitosan /liter of water

Leaf Area (cm²)

The study revealed that water stress intervals significantly influenced corn leaf area ($p < 0.0001$), as shown in Table 10. Plants under regular watering (A1) had the largest leaf area (71.70 cm²), while moderate (A2- 64.32 cm²) and severe drought (A3- 59.02 cm²) conditions led to smaller leaf areas.

This reduction support with previous studies (Shao et al., 2008; Farooq et al., 2009), which found that drought limits cell division and expansion, thereby restricting leaf growth. Smaller leaves may also act as a protective mechanism to minimize water loss (Blum, 2011). Because leaf area is critical for photosynthesis

and biomass production, its reduction under drought reflects decreased yield potential (Khatun et al., 2016).

Table 10 Leaf Area of OPV corn as affected by Water Stress Interval

Water Stress Interval	Leaf Area (cm ²) (<0.0001)
A1	71.70 ^a
A2	64.32 ^b
A3	59.02 ^c

Legend: Means within the column with the same superscript were not significantly different ($p > 0.05$); A1 - Regular Watering; A2-15 days; A3- 25 days

The study found that chitosan application significantly enhanced corn leaf area (Table 11), with a clear dose-dependent response. The largest leaf area (75.61 cm²) was observed in plants treated with B4- 150 ml/L chitosan significantly outperforming all other treatments. Intermediate levels also improved leaf area, 100 ml/L (B3) yielded 64.93 cm², and 50 ml/L (B2) yielded 61.62 cm², while the control (B1) recorded the smallest area (57.90 cm²).

These results are supported by previous research (Guan et al., 2009; Sharif et al., 2018; Iriti & Faoro, 2009), which noted that chitosan enhances cell division, stomatal function, hormonal balance, and

nutrient uptake, all of which contribute to better leaf development.

Table 11 Leaf Area of OPV corn as affected by Chitosan level (ml/L) as Antitranspirant

Chitosan as Antitranspirant	Leaf Area (cm ²) (0.05)
B1	57.90 ^d
B2	61.62 ^c
B3	64.93 ^b
B4	75.61 ^a

Legend: Means within the column with the same superscript were not significantly different ($p < 0.01$); B1- Control; B2- 50ml; B3- 100 ml; B4- 150ml

The study demonstrated that combining proper irrigation with chitosan application effectively improves corn leaf area and mitigates drought stress. Under regular watering (A1), leaf area increased progressively with chitosan dose, peaking at A1B4- 86.08 cm². Similarly, under moderate water stress (A2), A2B4 (75.19 cm²) showed the best leaf growth, and under severe stress (A3), A3B4 (64.57 cm²) outperformed untreated plants.

These results highlight chitosan's role in promoting cell elongation, chlorophyll synthesis, and physiological resilience even under limited water, consistent with findings by Farouk & Amany (2012), Khan et al. (2002), and Guan et al. (2009).

Table 12 Leaf Area of OPV Corn as affected by the Interaction between Water Stress Interval and Chitosan level (ml/L) as Antitranspirant

Treatment Combinations	Leaf Area (cm ²) (P value=0.0010)
A1B1	63.13±2.29
A1B2	65.80±2.35
A1B3	71.77±2.69
A1B4	86.08±0.62
A2B1	56.40±2.22
A2B2	61.62±0.95
A2B3	64.06±2.52
A2B4	75.19±1.48
A3B1	54.14±2.19
A3B2	57.44±2.52
A3B3	58.94±2.26
A3B4	64.57±0.07

Legend: A1B1 - Regular watering + Control; A1B2 - Regular watering + 50 ml chitosan /liter of water; A1B3 - Regular watering + 100 ml chitosan /liter of water; A1B4: Regular watering + 150 ml chitosan /liter of water; A2B1: 15 days (water stress interval) + Control; A2B2 - 15 days (water stress interval) + 50 ml chitosan /liter of water; A2B3 - 5 days (water stress interval) + 100 ml chitosan /liter of water; A2B4 - 15 days (water stress interval) + 150 ml chitosan /liter of water; A3B1 - 25 days (water stress interval) + Control ; A3B2 - 25 days (water stress interval) + 50 ml chitosan /liter of water; A3B3 - 25 days (water stress interval) + 100 ml chitosan /liter of water;

A3B4 - 25 days (water stress interval) + 150 ml chitosan /liter of water

Correlation between Fresh Weight and Dry Weight of Biomass

Regular watering (A1) produced the highest fresh weight (217.92 g), significantly greater than under A2 -15 day and A3- 25 days stress intervals, confirming water's role in turgor maintenance and growth. However, dry biomass percentage increased under drought, with A2 (30.89%) and A3 (28.75%) exceeding A1 (25.31%), indicating a physiological

adaptation to stress through reduced tissue hydration and improved osmotic adjustment.

This inverse relationship lower fresh weight but higher dry matter under drought demonstrates a strategic plant response that concentrates biomass

Regular irrigation favors fresh biomass accumulation, while moderate water stress (A2) enhances dry matter content, suggesting that regulated irrigation can be a useful strategy for optimizing corn biomass production in semi-arid conditions.

Table13 Correlation between Fresh Weight and Dry Weight of OPV corn as affected by Water Stress Interval (days)

Water Stress Interval	Fresh Weight (g) (<.0001)	Dry Biomass(%) (0.0001)
A1	217.92 ^a	25.31 ^b
A2	162.63 ^b	30.89 ^a
A3	151.67 ^b	28.75 ^a

Legend: Means within the column with the same superscript were not significantly different ($p>0.05$); A1 - Regular Watering; A2-15 days; A3- 25 days

Fresh weight increased with higher chitosan concentrations, from 151.11 g (B1) to 202.22 g (B4), showing improved turgor pressure and water use efficiency due to chitosan's semi-permeable film that reduces transpiration while allowing gas exchange. However, dry biomass percentage peaked at B3 (100 ml/L, 31.01%) and declined at B4 (25.42%), suggesting that B4's higher water content diluted structural biomass.

Overall, chitosan at 100 - 150 ml/L enhances corn growth. While 150 ml/L maximizes fresh biomass, 100 ml/L optimizes dry matter accumulation, making it more suitable for drought-prone environments where efficiency are critical in OPV corn cultivation.

Table 14 Correlation between Fresh Weight and Dry Weight of OPV corn as affected by Chitosan level (ml/L) as Antitranspirant

Chitosan as Antitranspirant	Fresh Weight (g) (<.0001)	Dry Biomass (%) (0.0017)
B1	151.11 ^c	28.42 ^{ab}
B2	172.22 ^b	28.42 ^{ab}
B3	184.07 ^{ab}	31.01 ^a
B4	202.22 ^a	25.42 ^b

Legend: Means within the column with the same superscript were not significantly different ($p<0.01$); B1- Control; B2- 50ml; B3- 100 ml; B4- 150ml

Table 15 shows the interaction between water stress intervals and chitosan concentrations on fresh weight and dry biomass percentage in OPV corn

Fresh weight, chitosan application (100-150 ml/L) increased fresh biomass across all watering levels. Under regular watering (A1), fresh weight rose from A1B1- 175.00 g to A1B4- 255.00 g. Even under moderate (A2) and severe (A3) drought, chitosan boosted fresh weight, demonstrating its role in improving turgor pressure and drought tolerance. While on, dry biomass (%), highest dry matter accumulation was seen in A2B1- 35.31% and A2B3 (33.24%), indicating stress induced carbon allocation. In A3, dry biomass was lowest in the untreated control (21.99%) but improved with chitosan, especially A3B3- 34.79%, reflecting enhanced photosynthetic efficiency. Under A1, dry biomass percentage declined with higher chitosan, due to greater water retention diluting dry matter.

Though the interaction was not statistically significant, the data clearly show that applying 100-150 ml/L chitosan, particularly under moderate drought, enhances both fresh biomass and dry matter accumulation, supporting its integration into drought management strategies for OPV corn.

Table 15 Correlation between Fresh Weight and Dry Weight of OPV corn as affected by the Interaction between Water Stress Interval and Chitosan level (ml/L) as Antitranspirant

Treatment Combinations	Fresh Weight (g) (P value=0.0875)	Dry Biomass (%) (P value=<.0001)	floral abortion. The similar impact of A2 and A3 supports Blum's (2011) threshold model, emphasizing
A1B1	175.00±25.00	27.98±3.84	
A1B2	208.33±40.48	24.68±5.27	
A1B3	233.33±2.08	25.00±0.26	
A1B4	255.00±10.94	23.56±1.20	
A2B1	141.67±2.36	35.31±1.08	
A2B2	158.33±3.21	30.54±0.96	
A2B3	165.53±3.55	33.24±1.28	
A2B4	185.00±18.52	24.49±2.62	
A3B1	136.67±1.85	21.99±5.15	
A3B2	150.00±5.07	30.03±1.20	
A3B3	153.33±2.25	34.79±0.79	
A3B4	166.67±11.41	28.21±1.67	

Legend: A1B1 - Regular watering + Control; A1B2 - Regular watering + 50 ml chitosan /liter of water; A1B3 - Regular watering + 100 ml chitosan /liter of water; A1B4: Regular watering + 150 ml chitosan /liter of water; A2B1: 15 days (water stress interval) + Control; A2B2 - 15 days (water stress interval) + 50 ml chitosan /liter of water; A2B3 - 5 days (water stress interval) + 100 ml chitosan /liter of water; A2B4 - 15 days (water stress interval) + 150 ml chitosan /liter of water; A3B1 - 25 days (water stress interval) + Control ; A3B2 - 25 days (water stress interval) + 50 ml chitosan /liter of water; A3B3 - 25 days (water stress interval) + 100 ml chitosan /liter of water; A3B4 - 25 days (water stress interval) + 150 ml chitosan /liter of water

Number of Corn Ear per Plot

Plants under A1- regular watering produced the highest number of ears (1.08), significantly more than those under 15 day (A2- 0.84) and 25 day (A3- 0.81) watering intervals, which did not differ significantly from each other. This highlights that even moderate drought can seriously affect reproductive development in corn.

The results agree with studies by Chaves et al. (2003) and Zinselmeyer et al. (2002), linking drought during critical stages like silking to pollination failure and

that stress intensity and timing, not just duration, are key to reproductive success. Findings also, agree with Zayed et al. (2017), who noted sharp declines in reproductive traits under prolonged drought, especially without interventions.

Table 16 Number of OPV Corn Ear as affected by Water Stress Interval

Water Stress Interval	Number of Corn Ear (<.0001)
A1	1.08 ^a
A2	0.84 ^b
A3	0.81 ^b

Legend: Means within the column with the same superscript were not significantly different (p>0.05); A1 -Regular Watering; A2-15 days; A3- 25 days

Table 17 shows that 100 ml/L (B3) and 150 ml/L (B4) chitosan treatments produced the highest number of ears (0.98), significantly more than the control (B- 0.82) and 50 ml/L (B2- 0.87). The absence of a significant difference between B3 and B4 suggests a saturation point at higher concentrations.

These findings support chitosan's role as an effective biostimulant, enhancing reproductive growth in OPV corn by improving nutrient uptake, hormone regulation, water use efficiency, and photosynthesis

(Khan et al., 2020; Sharif et al., 2018; Rouphael & Colla, 2020). The results also align with the hormesis theory (Calabrese & Blain, 2009), indicating that benefits may decline at excessive doses, while low doses (like 50 ml/L) may be insufficient to trigger growth responses (Farouk et al., 2011).

In conclusion, 100 -150 ml/L chitosan significantly improves ear production, with 100 ml/L as the optimal concentration for maximizing reproductive output in OPV corn.

Table 17 Number of Corn Ear of OPV corn as affected by Chitosan level (ml/L) as Antitranspirant

Chitosan as Antitranspirant	Number of Corn Ear (0.0001)
B1	0.82 ^b
B2	0.87 ^b
B3	0.98 ^a
B4	0.98 ^a

Legend: Means within the column with the same superscript were not significantly different ($p < 0.05$); B1- Control; B2- 50ml; B3- 100 ml; B4- 150ml

Under regular watering (A1), corn ear number increased modestly with rising chitosan levels from 1.00 to 1.20. However, under water stress conditions (A2 and A3), ear production declined ranging from 0.70 to 0.90, and chitosan had limited mitigating effects. This indicates that water stress was the dominant factor affecting ear formation, with chitosan offering only minor or inconsistent improvements.

These findings correspond with Chaves et al. (2003), who reported that drought during reproductive stages disrupts hormonal signaling and assimilate allocation, reducing ear development. Although chitosan has documented roles in enhancing stress responses (Khan et al., 2020; Sharif et al., 2018), its influence here was not strong enough to overcome drought effects. Slight gains under well-watered conditions support Rouphael and Colla (2020), who found chitosan's yield enhancing effects are most effective under non stress or mild stress conditions.

Table 18 Number of OPV Corn Ear as affected by the Interaction between Water Stress Interval and Chitosan level (ml/L as Antitranspirant

Treatment Combinations	Number of corn Ear (P value=0.5379)
A1B1	1.00±0.00
A1B2	1.00±0.00
A1B3	1.13±0.58
A1B4	1.20±0.10
A2B1	0.77±0.06
A2B2	0.83±0.06
A2B3	0.90±0.10
A2B4	0.87±0.06
A3B1	0.70±0.10
A3B2	0.77±0.06
A3B3	0.90±0.10
A3B4	0.87±0.06

Legend: A1B1 - Regular watering + Control; A1B2 - Regular watering + 50 ml chitosan /liter of water; A1B3 - Regular watering + 100 ml chitosan /liter of water; A1B4: Regular watering + 150 ml chitosan /liter of water; A2B1: 15 days (water stress interval) + Control; A2B2 - 15 days (water stress interval) + 50 ml chitosan /liter of water; A2B3 - 5 days (water stress interval) + 100 ml chitosan /liter of water; A2B4 - 15 days (water stress interval) + 150 ml chitosan /liter of water; A3B1 - 25 days (water stress interval) + Control ; A3B2 - 25 days (water stress interval) + 50 ml chitosan /liter of water; A3B3 - 25 days (water stress interval) + 100 ml chitosan /liter of water; A3B4 - 25 days (water stress interval) + 150 ml chitosan /liter of water

Diameter of Corn Ear (mm)

Table 19 shows that OPV corn under moderate water stress A2- 15 day interval produced the largest ear diameter at 36.86 mm, significantly greater than under regular watering, A1- 34.58 mm and severe stress A3- 34.71 mm, with no difference between A1 and A3.

This indicates that moderate drought may trigger a compensatory mechanism, enhancing ear diameter through resource reallocation a response supported by Lopes et al. (2011). In contrast, the A3- 25 day interval

likely exceeded the crop's stress threshold, limiting development, consistent with Farooq et al. (2009).

Table 19 Diameter of Corn Ear of OPV corn as affected by Water Stress Interval

Water Stress Interval	Corn Ear Diameter (mm) (0.0044)
A1	34.58 ^b
A2	36.86 ^a
A3	34.71 ^b

Legend: Means within the column with the same superscript were not significantly different ($p>0.05$);
A1 - Regular Watering;
A2-15 days; A3- 25 days

All chitosan treated corn plants B2 (50 ml/L), B3 (100 ml/L), and B4 (150 ml/L) produced significantly larger ear diameters (36.21 and 37.31 mm) than the untreated control B1 (30.95 mm), with no significant difference among the chitosan treatments.

These findings prove chitosan's effectiveness as a biostimulant for enhancing reproductive traits like ear diameter, likely due to its role in improving nutrient uptake, water use efficiency, antioxidant activity, and hormonal regulation.

Even 50 ml/L showed strong positive effects, while 100 ml/L may be optimal under the tested conditions. These results align with previous reports in maize and rice by Kumaraswamy et al. (2014).

Table 20 Diameter Corn Ear of OPV corn as affected by Chitosan level (ml/L) as Antitranspirant

Chitosan as Antitranspirant	Corn Ear Diameter (mm) (<0.0001)
B1	30.95 ^b
B2	36.21 ^a
B3	37.31 ^a
B4	37.07 ^a

Legend: Means within the column with the same superscript were not significantly different ($p<0.01$);
B1 - Control; B2- 50ml; B3- 100 ml; B4- 150ml

The largest ear diameter (42.19 mm) was recorded under moderate water stress, A2- 15 day interval combined with high chitosan B4- 150 ml/L, indicating that mild drought may enhance plant responsiveness to chitosan by stimulating antioxidant activity, osmotic regulation, and hormone signaling (Hadwiger, 2013; Gornik et al., 2008; Zeng & Luo, 2012).

Regular watering (A1), chitosan also improved ear diameter particularly at 50 ml/L (A1B2- 37.64 mm) and 100 ml/L (A1B3- 36.93 mm) though the effects were less pronounced, showing chitosan's dual role as both a growth enhancer and stress mitigator.

Control treatments (B1) showed the lowest ear diameters (29.29 - 32.73 mm) across all water levels, reinforcing the harmful impact drought stress. Even under severe drought (A3), chitosan especially at 100 ml/L (A3B3- 37.45 mm) still significantly improved ear size, demonstrating its potential to sustain yield traits in stressed environments.

Table 21 Diameter of Corn Ear of OPV corn as affected by the Interaction Between Water Stress Interval and Chitosan level (ml/L)

Treatment Combinations	Diameter of Corn Ear (mm) (P value=0.0005)
A1B1	29.29±1.30
A1B2	37.64±1.61
A1B3	36.93±1.36
A1B4	34.48±2.23
A2B1	32.73±1.42
A2B2	34.98±2.19
A2B3	37.55±1.97
A2B4	42.19±3.90
A3B1	30.84±1.30
A3B2	36.02±1.91
A3B3	37.45±3.44
A3B4	34.54±2.64

Legend: A1B1 - Regular watering + Control; A1B2 - Regular watering + 50 ml chitosan /liter of water; A1B3 - Regular watering + 100 ml chitosan /liter of water; A1B4: Regular watering + 150 ml chitosan /liter of water; A2B1: 15 days (water stress interval) + Control; A2B2 - 15 days (water stress interval) + 50

ml chitosan /liter of water; A2B3 - 5 days (water stress interval) + 100 ml chitosan /liter of water; A2B4 - 15 days (water stress interval) + 150 ml chitosan /liter of water; A3B1 - 25 days (water stress interval) + Control ; A3B2 - 25 days (water stress interval) + 50 ml chitosan /liter of water; A3B3 - 25 days (water stress interval) + 100 ml chitosan /liter of water; A3B4 - 25 days (water stress interval) + 150 ml chitosan /liter of water

Length of Corn Ear (cm)

The longest corn ears (11.61 cm) were observed under regular watering (A1), significantly longer than those under 15 day stress (A2- 10.16 cm) and slightly longer than 25 day stress (A3- 10.92 cm).

The most severe reduction occurred under moderate drought (A2), highlighting that water stress during critical stages like silking and ear elongation can drastically limit cob growth, as supported by Farooq et al. (2009). Interestingly, A3 or severe stress did not significantly differ from A1, suggesting potential adaptive mechanisms such as hormonal balance or metabolic adjustments (Tardieu, 2012).

The findings same with Oosterhuis et al. (2007), emphasizing that water stress reduces assimilate flow to reproductive organs, leading to shorter ears, and affirming that consistent irrigation during early reproductive stages is vital for optimal ear development.

Table 22 Length of Corn Ear of OPV corn as affected by Water Stress Interval

Water Stress Interval	Length of Corn Ear (cm) (0.0006)
A1	11.61 ^a
A2	10.16 ^b
A3	10.92 ^{ab}

Legend: Means within the column with the same superscript were not significantly different ($p>0.05$); A1 - Regular Watering; A2-15 days; A3- 25 days

Table 23 demonstrates that chitosan application significantly improves corn ear length, with 100 ml/L (B3) producing the longest ears (11.56 cm)

significantly longer than the control (B1- 10.08 cm). While 50 ml/L (B2) and 150 ml/L (B4) also increased ear length (11.07 cm and 10.86 cm, respectively), only the 100 ml/L dose showed a statistically significant improvement.

This indicate that 100 ml/L is the optimal concentration, likely due to enhanced photosynthesis, nutrient uptake, enzymatic activity, and hormonal balance, (El Hadrami et al., 2010 and Hidangmayum et al., 2019). The reduced effectiveness at 150 ml/L supports the idea of a threshold or saturation effect, where excessive chitosan may disrupt plant metabolism (Khan et al., 2020).

Chitosan at 100 ml/L is the most effective dose for increasing ear length in corn, confirming its role as a sustainable biostimulant when applied at optimal concentrations.

Table 23 Length of Corn Ear of OPV corn as affected by Chitosan level (ml/L) as Antitranspirant

Chitosan as Antitranspirant	Length of Corn Ear (cm) (0.0049)
B1	10.08 ^b
B2	11.07 ^{ab}
B3	11.56 ^a
B4	10.86 ^{ab}

Legend: Means within the column with the same superscript were not significantly different ($p<0.01$); B1- Control; B2- 50ml; B3- 100 ml; B4- 150ml

The longest corn ears were recorded under A1B3 (regular watering + 100 ml/L chitosan), followed by A2B3 and A2B4, indicating that chitosan at 100 - 150 ml/L enhances ear development under both optimal and moderate drought conditions. In contrast, A3B1 (severe drought without chitosan) had the shortest ears, demonstrating the damaging effects of prolonged water stress without biostimulant intervention.

These findings support previous studies (El-Tanany et al., 2012; Kumaraswamy et al., 2020) showing that chitosan improves drought tolerance by maintaining

turgor, enhancing photosynthesis, and regulating stress related hormones and antioxidant activity.

Table 24 Length of Corn Ear of OPV corn as affected by the Interaction between Water Stress Interval and Chitosan level (ml/L) as Antitranspirant

Treatment Combinations	Length of Corn Ear (cm) (P value=0.0001)
A1B1	10.49±0.65
A1B2	11.69±0.48
A1B3	12.45±1.12
A1B4	11.80±0.32
A2B1	8.89±1.85
A2B2	10.52±0.61
A2B3	11.21±0.82
A2B4	10.00±0.33
A3B1	10.87±1.10
A3B2	11.01±1.24
A3B3	11.01±0.78
A3B4	10.78±1.07

Legend: A1B1 - Regular watering + Control; A1B2 - Regular watering + 50 ml chitosan /liter of water; A1B3 - Regular watering + 100 ml chitosan /liter of water; A1B4: Regular watering + 150 ml chitosan /liter of water; A2B1: 15 days (water stress interval) + Control; A2B2 - 15 days (water stress interval) + 50 ml chitosan /liter of water; A2B3 - 5 days (water stress interval) + 100 ml chitosan /liter of water; A2B4 - 15 days (water stress interval) + 150 ml chitosan /liter of water; A3B1 - 25 days (water stress interval) + Control ; A3B2 - 25 days (water stress interval) + 50 ml chitosan /liter of water; A3B3 - 25 days (water stress interval) + 100 ml chitosan /liter of water; A3B4 - 25 days (water stress interval) + 150 ml chitosan /liter of water

Corn Ear Weight (g)

Table 25 shows a clear decline in corn ear weight with increasing water stress at A1 (regular watering) had the highest ear weight (72.79 g), followed by A2 (15 day interval) at 58.50 g, and A3 (25 day interval) at the lowest (48.54 g). This progressive reduction highlights the negative impact of drought on reproductive processes, including nutrient uptake, photosynthesis, especially during silking and grain filling stages.

The results support Farooq et al. (2009) and Kang et al. (2011), emphasizing that while moderate drought may be tolerable, prolonged water deficit causes irreversible tissue damage and reduced yield.

Ear weight is a sensitive indicator of drought impact, and regular irrigation is essential to sustain productivity, as extended stress periods (like 25 day intervals) drastically reduce corn ear development and final yield.

Table 25 Ear Weight of OPV corn as affected by Water Stress Interval

Water Stress Interval	Corn Ear Weight (g) (<.0001)
A1	72.79 ^a
A2	58.50 ^b
A3	48.54 ^c

Legend: Means within the column with the same superscript were not significantly different ($p>0.05$); A1 - Regular Watering; A2-15 days; A3- 25 days

Table 26 shows that chitosan significantly improved corn ear weight, with the highest yield at 100 ml/L (68.39 g), followed by 150 ml/L (64.22 g) and 50 ml/L (58.61 g), all outperforming the control (48.56 g). These results confirm 100 ml/L as the optimal dose, providing the best balance of growth stimulation and stress tolerance.

The improvement is attributed to chitosan's effects on nutrient uptake, water-use efficiency, hormonal activity, antioxidant defense, and stomatal regulation, which together enhance dry matter allocation to ears. The lack of added benefit at 150 ml/L suggests a saturation point, where excess chitosan may no longer boost yield and could even hinder metabolic efficiency.

Table 26 Ear Weight of OPV corn as affected by Chitosan level (ml/L) as Antitranspirant

Chitosan as Antitranspirant	Corn Ear Weight (g) (<0.0001)
B1	48.56 ^c
B2	58.61 ^b
B3	68.39 ^a
B4	64.22 ^a

Legend: Means within the column with the same superscript were not significantly different ($p < 0.01$); B1- Control; B2- 50ml; B3- 100 ml; B4- 150ml

Statistically significant interaction ($p = 0.0369$) between water stress intervals and chitosan levels on corn ear weight, as shown in Table 27. This means the effectiveness of chitosan depends on the level of water stress. Under regular watering (A1), ear weight

increased with chitosan up to 100 ml/L (80.17 g), but slightly declined at 150 ml/L (74.33 g), indicating a possible threshold.

Under moderate (A2 -15 days) and severe (A3 - 25 days) water stress, 100 ml/L chitosan significantly improved ear weight compared to the control, suggesting its strong drought-mitigating effects. These findings conclude with studies (Khan et al., 2002; Gornik et al., 2008; Hadwiger, 2013; El-Tanahy et al., 2012), which highlight chitosan's role in enhancing plant stress tolerance. Overall, the interaction confirms that chitosan is most effective under water limited conditions and could be a valuable tool in drought management strategies.

Table 27 Ear Weight of OPV corn as affected by the Interaction Between Water Stress Interval and Chitosan level (ml/L)

Treatment Combinations	Corn Ear Weight (g) ($P \text{ value} = 0.0369$)
A1B1	65.00 $\pm$ 4.76
A1B2	71.67 $\pm$ 3.81
A1B3	80.17 $\pm$ 3.33
A1B4	74.33 $\pm$ 3.71
A2B1	42.33 $\pm$ 3.96
A2B2	56.67 $\pm$ 0.75
A2B3	70.00 $\pm$ 2.29
A2B4	65.00 $\pm$ 6.29
A3B1	38.33 $\pm$ 1.07
A3B2	47.50 $\pm$ 1.97
A3B3	55.00 $\pm$ 0.53
A3B4	53.33 $\pm$ 0.40

Legend: A1B1 - Regular watering + Control; A1B2 - Regular watering + 50 ml chitosan /liter of water; A1B3 - Regular watering + 100 ml chitosan /liter of water; A1B4: Regular watering + 150 ml chitosan /liter of water; A2B1: 15 days (water stress interval) + Control; A2B2 - 15 days (water stress interval) + 50 ml chitosan /liter of water; A2B3 - 5 days (water stress interval) + 100 ml chitosan /liter of water; A2B4 - 15 days (water stress interval) + 150 ml chitosan /liter of water; A3B1 - 25 days (water stress interval) + Control ; A3B2 - 25 days (water stress interval) + 50 ml chitosan /liter of water; A3B3 - 25 days (water

stress interval) + 100 ml chitosan /liter of water; A3B4 - 25 days (water stress interval) + 150 ml chitosan /liter of water

Correlation between Yield per Plot and Yield per Hectare

Table 28 highlights the significant impact of water stress intervals on the yield performance of OPV corn, with both yield per plot and yield per hectare showing highly significant differences ($p < 0.0001$). A strong positive correlation between the two parameters confirms that as water stress increases, yield declines.

The highest yields were observed under regular watering (A1), with 24.26 g per plot and 1,722.50 kg per hectare. In contrast, yields dropped significantly at 15 day (A2) and 25 day (A3) stress intervals, with the lowest yields recorded under A3 (16.17 g per plot; 1,176.33 kg/ha).

These reductions agree with the findings by Zlatev and Lidon (2012), who linked extended water stress to oxidative damage and impaired grain filling. Similarly, Khalili et al. (2013) emphasized the critical importance of water during flowering and grain filling, where even moderate stress can drastically reduce yields. Overall, the results underscore OPV corn's sensitivity to water deficiency and highlight the importance of adequate irrigation for maintaining optimal yield.

Table 28 Correlation between Yield per Plot and Yield per Hectare of OPV corn as affected by Water Stress Interval

Water Stress Interval	Yield per Plot (g) (.0001)	Yield per Hectare (kg) (.0001)
A1	24.26 ^a	1722.50 ^a
A2	19.50 ^b	1376.48 ^b
A3	16.17 ^c	1176.33 ^c

Legend: Means within the column with the same superscript were not significantly different ($p > 0.05$); A1 -Regular Watering; A2-15 days; A3- 25 days

Strong positive correlation between yield per plot and yield per hectare in OPV corn in response to different chitosan concentrations, with both parameters exhibiting highly significant differences ($p < 0.0001$), Table 29. Chitosan application notably increased yield compared to the control (B1), with the highest yield recorded at 100 ml/L (B3), followed by 150 ml/L (B4), 50 ml/L (B2), and the untreated control. This indicates that 100 ml/L is the most effective concentration for enhancing yield.

Chitosan's role as an antitranspirant forming a semi-permeable film that limits water loss while supporting photosynthesis (Kumaraswamy et al., 2020) likely

contributed to these yield improvements. The findings support chitosan's potential as a sustainable, eco-friendly, and cost-effective tool for improving water use efficiency and yield, especially in drought-prone areas.

Table 29 Correlation between Yield per Plot and Yield per Hectare of OPV corn as affected by Chitosan level (ml/L) as Antitranspirant

Chitosan as Antitranspirant	Yield per Plot (g) (<.0001)	Yield per Hectare (kg) (<.0001)
B1	16.18 ^d	1121.22 ^d
B2	19.53 ^c	1420.33 ^c
B3	22.80 ^a	1657.89 ^a
B4	21.40 ^b	1500.00 ^b

Legend: Means within the column with the same superscript were not significantly different ($p < 0.01$); B1- Control; B2- 50ml; B3- 100 ml; B4- 150ml

Statistically significant interactions between water stress intervals and chitosan levels on both yield per plot ($p = 0.0015$) and yield per hectare ($p = 0.0240$), as presented in Table 30. These results confirm that corn yield is jointly influenced by water availability and chitosan application.

The highest yield per plot (26.72 g) and per hectare (1,943.33 kg/ha) were achieved with regular watering and 100 ml/L chitosan (A1B3). Under moderate (A2) and severe (A3) water stress, 100 ml/L chitosan (A2B3 and A3B3) still significantly boosted yield compared to their respective controls, demonstrating chitosan's ability to mitigate drought effects.

This result supports the study conducted by Mondal et al. (2013), which noted chitosan's dose-dependent benefits, with optimal results around 100 ml/L. Overall, the study concludes that chitosan, especially at 100 ml/L, is an effective antitranspirant and yield enhancer under both optimal and water-limited conditions.

Table 30 Correlation between Yield per Plot and Yield per Hectare of OPV corn as Affected by the Interaction between Water Stress Interval and Antitranspirant Chitosan level (ml/L)

Treatment Combinations	Yield per plot (g) (P value=0.0015)	Yield per Hectare (kg) (P value=0.0240)
A1B1	21.67±1.37	1409.00±66.00
A1B2	23.87±0.38	1735.67±72.45
A1B3	26.72±1.42	1943.33±43.04
A1B4	24.77±0.70	1802.00±53.29
A2B1	14.11±0.45	1026.33±9.96
A2B2	18.89±0.82	1373.67±28.52
A2B3	23.33±0.40	1697.00±75.58
A2B4	21.67±0.50	1408.90±83.37
A3B1	12.77±0.40	928.33±6.41
A3B2	15.83±0.46	1151.67±8.49
A3B3	18.33±0.25	1333.33±70.07
A3B4	17.76±1.27	1292.00±94.52

Legend: A1B1 - Regular watering + Control; A1B2 - Regular watering + 50 ml chitosan /liter of water; A1B3 - Regular watering + 100 ml chitosan /liter of water; A1B4: Regular watering + 150 ml chitosan /liter of water; A2B1: 15 days (water stress interval) + Control; A2B2 - 15 days (water stress interval) + 50 ml chitosan /liter of water; A2B3 - 5 days (water stress interval) + 100 ml chitosan /liter of water; A2B4 - 15 days (water stress interval) + 150 ml chitosan /liter of water; A3B1 - 25 days (water stress interval) + Control ; A3B2 - 25 days (water stress interval) + 50 ml chitosan /liter of water; A3B3 - 25 days (water stress interval) + 100 ml chitosan /liter of water; A3B4 - 25 days (water stress interval) + 150 ml chitosan /liter of water

Relative Water Content (%)

Table 21 show that water stress intervals have a highly significant effect ($p < 0.0001$) on the relative water content (RWC) of corn leaves, a key indicator of drought tolerance. RWC decreased as the duration between watering increased, with the highest value recorded under regular watering (A1) at 83.52%, compared to significantly lower values under 15 day (A2- 73.05%) and 25 day (A3- 69.65%) intervals. The lack of significant difference between A2 and A3 suggests that even moderate stress notably disrupts water balance.

These findings support the studies of (Farooq et al., 2009; Kumar et al., 2021; Zhou et al., 2018) which emphasize that drought reduces RWC, impairs physiological processes, and increases vulnerability to stress. RWC's sensitivity makes it a reliable early indicator of drought impact.

Increasing water stress intervals significantly reduce RWC, compromising plant hydration and performance. Regular irrigation is essential to maintain cellular water status and support optimal corn growth under stress-prone conditions.

Table 31 Relative Water Content of OPV corn as Affected by Water Stress Interval (days)

Water Stress Interval	Relative Water Content (%) (.0001)
A1	83.52 ^a
A2	73.05 ^b
A3	69.65 ^b

Legend: Means within the column with the same superscript were not significantly different ($p>0.05$); A1 - Regular Watering; A2-15 days; A3- 25 days

Table 32, reveal that chitosan concentration has a highly significant effect on the relative water content

(RWC) of corn leaves ($p = 0.0001$), a key indicator of plant water status and drought resilience. The highest RWC was recorded at 150 ml/L (B4) with 83.61%, significantly higher than the control (B1: 70.79%) and lower concentrations 50 ml/L (B2- 74.88%) and 100 ml/L (B3- 72.35%). Only B4 showed a statistically significant improvement in RWC.

This suggests that a higher chitosan dose (150 ml/L) is most effective in enhancing cellular hydration, likely by improving antioxidant activity and regulating water loss (Khan et al., 2020; Sathiyabama & Manikandan, 2018). The intermediate concentrations did not differ significantly from the control, possibly due to insufficient physiological stimulation at lower doses, consistent with the dose-dependent effects described by Sharif et al. (2018).

Table 32 Relative Water Content of OPV corn as affected by Chitosan level (ml/L) as Antitranspirant

Chitosan as Antitranspirant	Relative Water Content (0.0001)
B1	70.79 ^b
B2	74.88 ^b
B3	72.35 ^b
B4	83.61 ^a

Legend: Means within the column with the same superscript were not significantly different ($p < 0.01$); B1- Control; B2- 50ml; B3- 100 ml; B4- 150ml

Table 33 reveal a statistically significant interaction ($p = 0.0018$) between water stress intervals and chitosan concentrations on the relative water content (RWC) of corn, indicating that chitosan's effectiveness depends on the level of water stress.

Under regular watering (A1), relative water content increased consistently with higher chitosan levels, peaking at 88.31% with 150 ml/L (A1B4), supporting previous findings on chitosan's role in enhancing membrane stability and osmotic adjustment. Under moderate stress (A2), only the highest chitosan dose (A2B4) led to a significant increase in relative water content (91.21%), while lower concentrations showed limited or negative effects highlighting the importance

of sufficient dosage under stress. In severe stress conditions (A3), RWC was lower overall, but still improved slightly with increasing chitosan, from 67.03% (A3B1) to 71.32% (A3B4), indicating some protective effect even under harsh drought.

Findings confirm that the combination of proper irrigation and chitosan application, particularly at 150 ml/L, enhances corn's water retention and drought resilience across varying stress levels.

Table 33 Relative Water Content (RWC) of OPV corn as affected by the Interaction between Water Stress Interval and Chitosan level (ml/L) as Antitranspirant

Treatment Combination	Relative Water Content (%) (P value=0.0018)
A1B1	77.52±1.25
A1B2	83.35±0.74
A1B3	84.89±2.56
A1B4	88.31±5.23
A2B1	67.80±4.29
A2B2	71.83±5.04
A2B3	61.36±5.26
A2B4	91.21±10.64
A3B1	67.03±5.72
A3B2	69.45±5.90
A3B3	70.80±2.69
A3B4	71.32±6.07

Legend: A1B1: Regular watering + Control; A1B2 : Regular watering + 50 ml chitosan /liter of water; A1B3 : Regular watering + 100 ml chitosan /liter of water; A1B4: Regular watering + 150 ml chitosan /liter of water; A2B1: 15 days (water stress interval) + Control; A2B2: 15 days (water stress interval) + 50 ml chitosan /liter of water; A2B3: 15 days (water stress interval) + 100 ml chitosan /liter of water A2B4: 15 days (water stress interval) + 150 ml chitosan /liter of water ; A3B1 : 25 days (water stress I nterval) + Control ; A3B2 : 25 days (water stress interval) + 50 ml chitosan /liter of water ; A3B3 : 25 days (water stress interval) + 100 ml chitosan /liter of water; A3B4: 25 days (water stress interval) + 150 ml chitosan /liter of water

Excised Leaf Water Retention (%)

Varying water stress intervals had no statistically significant effect on excised leaf water retention (ELWR) in OPV corn ($p = 0.9480$), table 34. All treatments regular watering (A1- 11.78%), 15 day interval (A2- 11.64%), and 25 day interval A3- 11.66% produced similar ELWR values.

This result suggests that corn leaves maintained a stable water retention capacity regardless of water stress, possibly due to inherent genotypic traits or protective physiological mechanisms. While previous studies (Blum, 2011a; Sánchez-Rodríguez et al., 2010) found ELWR sensitive to drought, the stability observed here implies that this parameter may not be a reliable indicator of water stress response in this context.

Table 34 Excised Leaf Water Retention of OPV corn as affected by Water Stress Interval

Legend: Means within the column with the same superscript were not significantly different ($p > 0.05$); A1 – Regular

Water Stress Interval	Excised Leaf Water Retention (0.9480)
A1	11.78 ^a
B2	11.64 ^a
A3	11.66 ^a

Watering; A2-15 days; A3- 25 days

Varying chitosan concentrations had no significant effect on excised leaf water retention (ELWR) in corn ($p = 0.9905$). All treatments control (B1), 50 ml/L (B2), 100 ml/L (B3), and 150 ml/L (B4) produced statistically similar ELWR values, ranging from 11.59% to 11.75%.

This uniformity suggests that chitosan did not significantly influence the leaf's water retention capacity after excision, possibly due to limited effects on cuticular properties or because physiological benefits from chitosan are not reflected in this parameter. As noted by Blum (2011), ELWR assesses cuticular transpiration and membrane stability, but its responsiveness to biostimulants like chitosan may

vary based on genotype, growth stage, and environmental conditions.

The chitosan application did not affect ELWR in this study, indicating that this trait may not be sensitive enough to detect chitosan-induced changes in water retention under the tested conditions.

Table 35 Excised Leaf Water Retention of OPV corn as affected by Chitosan level (ml/L) as Antitranspirant

Chitosan as Antitranspirant	Excised Leaf Water Retention (0.9905)
B1	11.59 ^a
B2	11.73 ^a
B3	11.75 ^a
B4	11.70 ^a

Legend: Means within the column with the same superscript were not significantly different ($p < 0.01$); B1- Control; B2- 50ml; B3- 100 ml; B4- 150ml

Table 36, reveal that the interaction between water stress intervals and chitosan concentrations had no significant effect on excised leaf water retention (ELWR) in corn ($p = 1.0000$). All treatment combinations ranging from regular to severe water stress and varying chitosan doses produced statistically similar ELWR values (11.48% to 11.85%), with minimal variation.

This lack of interaction suggests that excised leaf water retention is not influenced by the combined effects of drought and chitosan treatment, reinforcing earlier findings that this trait remains stable regardless of external stress or biostimulant input. As noted also, by Blum (2011a), ELWR is a conservative physiological trait largely governed by structural leaf properties, which are less responsive to short-term interventions. Similarly, Ali et al. (2017) concluded that while chitosan enhances drought tolerance via osmotic and antioxidative pathways, these mechanisms may not significantly affect post-detachment water retention unless stress is extreme or prolonged.

Table 36 Excised Leaf Water Retention of OPV corn as affected by the Interaction between Water Stress Interval and Chitosan level (ml/L) as Antitranspirant

Treatment Combinations	Excised Leaf Water Retention (%) (P value=1.0000)
A1B1	11.77±0.30
A1B2	11.80±0.51
A1B3	11.85±0.38
A1B4	11.68±0.33
A2B1	11.48±0.85
A2B2	11.71±2.23
A2B3	11.66±1.42
A2B4	11.71±0.75
A3B1	11.53±1.44
A3B2	11.66±1.05
A3B3	11.73±1.12
A3B4	11.72±0.03

Legend: A1B1: Regular watering + Control; A1B2 : Regular watering + 50 ml chitosan /liter of water; A1B3 : Regular watering + 100 ml chitosan /liter of water; A1B4: Regular watering + 150 ml chitosan /liter of water; A2B1: 15 days (water stress interval) + Control; A2B2: 15 days (water stress interval) + 50 ml chitosan /liter of water A2B3: 15 days (water stress interval) + 100 ml chitosan /liter of water A2B4: 15 days (water stress interval) + 150 ml chitosan /liter of water ; A3B1 : 25 days (water stress interval) + Control ; A3B2 : 25 days (water stress interval) + 50 ml chitosan /liter of water; A3B3 25 days (water stress interval) + 100 ml chitosan /liter of water; A3B4: 25 days (water stress interval) + 150 ml chitosan /liter of water

IV. CONCLUSION

Results of this study do not fully align with the initial hypotheses about the effects of water stress intervals, chitosan application levels, and their interaction on glutinous corn OPV growth, yield, and physiological traits. Water stress, particularly at longer intervals (15 and 25 days), significantly reduced most growth and yield parameters and lowered relative water content, confirming its harmful impact on crop performance. In contrast, excised leaf water retention was unaffected by drought.

Chitosan application, at 100ml/L - 150 ml/L, significantly enhanced growth, yield components, and relative water content, demonstrating its role as an effective biostimulant to improve water retention and mitigate drought effects. However, ELWR remained stable across chitosan levels.

Importantly, a significant interaction between water stress and chitosan was found for RWC, indicating that chitosan's positive effects are most pronounced under moderate drought stress, suggesting a mutual interaction to enhance drought resilience in OPV corn. Overall, this study conclude the potential of chitosan treatment to partially offset the negative effects of water stress, with relative water content serving as a reliable physiological indicator of stress response and mitigation. These findings support the integration of antitranspirant chitosan in drought management strategies for OPV corn cultivation.

ACKNOWLEDGEMENT

This research marks a significant milestone in my professional journey, and I would like to extend my heartfelt gratitude to the following institutions and individuals whose invaluable support and contributions have made the completion of this study possible. From the challenging proposal writing stage, the demanding yet fulfilling chitosan as antitranspirant experiment, to the intensive data analysis and final manuscript preparation.

Deeply grateful to Enya Marie D. Apostol, University President, for her approval of the conduct of this study and for her words of encouragement and insightful advice that reinforced the objectivity of this research. Sincere thanks to Dr. Christian B. Apostol, her Adviser for the unwavering guidance and commitment throughout the development of this study, from conceptualization to the finalization of the manuscript. I also extend my appreciation to the members of the advisory committee whose expertise, constructive feedback, and meaningful suggestions have greatly enriched this research paper: Dr. Marcella S. Icalla, Chairperson; Dr. Mercedenia M. Ureta, Content Specialist; Dr. Nora C. Cabaral-Lasaca, Method Specialist; Dr. Alice R Ramos; English Critique, Mr. Jayson N. Erondo, External Expert

Priceless appreciation is extended to her former classmates, friends and especially to her colleague at Provincial Agriculturist Office, for moral support, encouragement, and kind assistance throughout the research .

Her deepest gratitude goes to her loving and understanding family, whose steadfast prayers, sacrifices, and emotional support given to the author and served as her foundation and source of strength in completing this endeavor.

Above all, I thank Almighty God, my Lord, Savior, and Light, for surrounding her with amazing people, and for His guidance, provisions, and grace during the most rigorous and challenging phases of this study, to You be all the honor and glory.

REFERENCES

- [1] Abdel-Aziz, S. M., et al. (2006). The effect of chitosan on growth and stress tolerance in plants under drought conditions. *Arab Journal of Biotechnology*, 9(2), 311- 322.
- [2] Ali, M. H., El-Sayed, H. M., & El-Nagar, G. R. (2017). Effect of irrigation intervals and foliar application of micronutrients on maize growth and productivity. *Journal of Plant Production*, 8(9), 875- 881.
- [3] Almeida, L. G., Magalhes, P. C., & Karam, D. (2018). Chitosan application in the induction of water deficit tolerance in maize plants.
- [4] Anjum, S. A., et. Al.,(2011). Morphological, physiological and biochemical responses of plants to drought stress. *African Journal of Agricultural Research*, 6(9), 2026-2032.
- [5] Blum, A. (2011a). Drought resistance is it really a complex trait. *Functional Plant Biology*, 38(10), 753 - 757.
- [6] Boonlertnirun, S., Suvannasara, R., & Promsomboon, P. (2011). Application of chitosan for reducing chemical fertilizer uses in waxy corn growing. *Thai Journal of Agricultural Science*, 44(5), 22-28.
- [7] Cerpacio, R. V. (2004). Maize in the Philippines: Production Systems Constraints, and research priorities.
- [8] Chaves, M. M., Maroco, J. P., & Pereira, J. S. (2003). Understanding plant responses to drought-from genes to the whole plant. *Functional Plant Biology*, 30(3), 239-264.
- [9] DA PhilRice- Philippine Rice Research Institute. (2019). Golden apple snail: A major pest in Philippine rice fields. <https://www.philrice.gov.ph>.
- [10] El Hadrami, A., Adam, L. R., El Hadrami, I., & Daayf, F. (2010). Chitosan in plant protection. *Marine Drugs*, 8(4), 968-987.
- [11] El-Tanahy, A. M., Fawzy, Z. F., & Abd El-Rhman, I. E. (2012). Response of tomato plants to chitosan and amino acids foliar application under different levels of nitrogen fertilizer. *Journal of Applied Sciences Research*, 8(2), 1131-1137.
- [12] Farooq, M., Wahid, A., Kobayashi, N., Fujita, D., & Basra, S. M. A. (2009). Plant drought stress: Effects, mechanisms and management. *Agronomy for Sustainable Development*, 29, 185-212. <https://doi.org/10.1051/agro:2008021>.
- [13] Farouk, S., & Amany, A. A. (2012). Improving growth and yield of cowpea by foliar application of chitosan under water stress. *Egyptian Journal of Biology*, 14, 14-26.
- [14] Farouk, S., Mosa, A. A., & Taha, A. A. (2011). Protective effect of humic acid and chitosan on radish (*Raphanus sativus* L.) plants subjected to cadmium stress. *Journal of Stress Physiology & Biochemistry*, 7(3), 121-136.
- [15] Flexas, J., & Medrano, H. (2002). Drought-inhibition of photosynthesis in C3 plants: stomatal and non-stomatal limitations revisited. *Annals of Botany*, 89(2), 183-189.
- [16] Gopal, J., & Muthu, M. (2019). Sustainable ecofriendly phytoextract mediated one pot green recovery of chitosan. *Scientific Reports*.
- [17] Gornik, K. et.al., (2008b). The effect of chitosan on rooting of grapevine cuttings and on subsequent plant growth under drought and temperature stress. *Journal of Fruit and Ornamental Plant Research*, 16(3), 333-343.
- [18] Guan, Y.et.al., (2009). Seed priming with chitosan improves maize germination and

- seedling growth in relation to physiological changes under low temperature stress. *Seed Science and Technology*, 37(2), 501-510.
- [19] Hadwiger, L. A. (2013). Multiple effects of chitosan on plant systems: solid science or hype. *Plant Science*, 208, 42-49.
- [20] Hassnain, A. B. et.al., (2019). Efficacy of chitosan on performance of tomato (*Lycopersicon esculentum* L.) plant under water stress condition. *Pakistan Journal of Agriculture Research*.
- [21] Hidangmayum, A.et.al., (2019). Application of chitosan on seed and plant growth attributes in maize (*Zea mays* L.). *International Journal of Current Microbiology and Applied Sciences*, 8(1), 1027-1036. <https://doi.org/10.20546/ijcmas.2019.801.112>.
- [22] Hsiao, T. C., Acevedo, E., Fereres, E., & Henderson, D. W. (2000). Stress metabolism: Water stress, growth, and osmotic adjustment. In D. W. Rains, R. C. Valentine, A. Hollaender, & A. San Pietro (Eds.), *Genetic engineering of osmoregulation: Impact on plant productivity for food, chemicals, and energy* (pp. 281-305).
- [23] Iriti, M., & Faoro, F. (2009). Chitosan as a MAMP, searching for a PRR. *Plant Signaling & Behavior*, 4(1), 66-68. <https://doi.org/10.4161/psb.4.1.7404>
- [24] Islam, M. S., Rahman, M. M., & Hasan, M. M. (2017). Properties and agricultural applications of chitosan derived from crustacean shells. *Journal of Natural Polymers*, 8(4), 233-245.
- [25] Kang, S.et.al., (2011). Effects of limited irrigation on yield and water use efficiency of maize in the Loess Plateau of China. *Agricultural Water Management*, 78(3), 241-252. [https://doi.org/10.1016/S0378-3774\(05\)00064-6](https://doi.org/10.1016/S0378-3774(05)00064-6).
- [26] Katiyar, A., Singh, R., & Sharma, P. (2015). Role of chitosan as a biostimulant for improving drought tolerance in plants. *Plant Physiology and Biochemistry*, 95, 34-42.
- [27] Khan, W., Prithiviraj, B., & Smith, D. L. (2002). Chitosan and chitinolytic compounds: Plant growth promoters and elicitors of defense response. *Canadian Journal of Plant Science*, 82(3), 381-389. <https://doi.org/10.4141/P01-038>.
- [28] Khan, W., Prithiviraj, B., & Smith, D. L. (2002). Effect of foliar application of chitin and chitosan on plant growth promotion and yield of soybean. *Journal of Plant Nutrition*, 25(1), 91-101.
- [29] Khan, W., Prithiviraj, B., & Smith, D. L. (2002). Effect of foliar application of chitin and chitosan oligosaccharides on photosynthesis of maize and soybean. *Photosynthetica*, 40, 621-624.
- [30] Khan, M. N., Mobin, M., Abbas, Z., & Alamri, S. A. (2020). Role of chitosan and its derivatives in abiotic stress tolerance in plants: Recent developments. *International Journal of Biological Macromolecules*, 164, 2088-2100. <https://doi.org/10.1016/j.ijbiomac.2020.07.160>
- [31] Khan, M. N.et.al.,(2020). Chitosan as a biostimulant in horticulture. *Scientia Horticulturae*, 274, 109506. <https://doi.org/10.1016/j.scienta.2020.109506>
- [32] Khan, W. M., Ali, S., Rizwan, M., Noreen, S.,(2020). Chitosan enhances drought tolerance in maize by improving physiological and biochemical attributes. *Environmental Science and Pollution Research*, 27(12), 13461-13471.
- [33] Khatun, A., Kabir, M. H., & Islam, M. R. (2016). Response of maize to water stress at different growth stages. *Progressive Agriculture*, 27(3), 274-281. <https://doi.org/10.3329/pa.v27i3.32182>.
- [34] Kimi M., Hamdi M.H., (2023). Direct extraction of chitosan from snail shells by natural deep eutectic solvent. *Universiti Malaysia Sarawak. Current Chemistry Letters* 12 (2023) 275-280.
- [35] Kocieka, J., Liberacki, D., & Strozecki, M. (2023). The role of antitranspirants in mitigating drought stress in plants of the grass family (Poaceae). A review. *Sustainability*. <https://doi.org/10.3390/su15129165>.
- [36] Kumar, M. N. V. R., Muzzarelli, R. A. A., Muzzarelli, C.,(2009). Chitosan chemistry and pharmaceutical perspectives. *Chemical Reviews*, 104(12), 6017- 6084.

- [37] Kumaraswamy, R. V.et.al.,(2020). Engineered chitosan-based nanomaterials: Mechanisms and applications in plants. *International Journal of Biological Macromolecules*, 165, 2952-2966.
- [38] Kumaraswamy, R. V. (2014). Foliar application of chitosan improves growth and yield attributes in rice. In *Application of Chitosan in Rice Production*.
- [39] Larasati, D. F., Priyanto, A. D., & Widodo, S. (2023). Characterization of chitosan from golden apple snail shells and its potential agricultural applications. *Journal of Biopolymer Research*, 16(1), 55-64.
- [40] Li, Y., Xu, Y., & Chen, Y. (2020). Effects of drought regimes on growth and physiological traits of a typical shrub species in subtropical China. *Global Ecology and Conservation*.
- [41] Lopes, M. S., Reynolds, M. P., Jalal-Kamali, M. R., Moussa, M., Feltaous, Y., (2011). The role of drought tolerance in wheat improvement. *Crop and Pasture Science*, 62(4), 303-311.
- [42] Mondal, M. M. A.,(2012). Effect of foliar application of chitosan on growth and yield in mungbean. *International Journal of Agriculture and Biology*, 14(6), 1101-1105.
- [43] Mondal, M. M. A.,(2013). Foliar application of chitosan alters the growth and yield of maize (*Zea mays* L.). *International Journal of Agronomy and Plant Production*, 4(11), 2555-2560.
- [44] Mondal, M. M. A., & Putsch, A. B. (2013). Foliar application of chitosan improves growth and yield in maize. *Journal of Food, Agriculture & Environment*, 11(2), 520-523.
- [45] Nanyang Technological University, Singapore. (2020). Microbial extraction of chitin from seafood waste using sugars derived from fruit waste-stream. Retrieved from <http://www.ntu.edu.sg>.
- [46] Oosterhuis, D. M., Loka, D. A., & Raper, T. B. (2007). Physiological response of maize to water deficit stress. *Proceedings of the World Cotton Research Conference*, 5, 30-35.
- [47] Pongprayoon, W., Siringam, T., Panya, A., & Roytrakul, S. (2020). Application of chitosan in plant defense responses to biotic and abiotic stress. <https://doi.org/10.14416/j.asep.2020.12.07>.
- [48] Riaz, A., Nawaz, H., & Cheema, M. A. (2013). Effect of water stress on growth and yield components of maize varieties. *Journal of Animal and Plant Sciences*, 23(5), 1450-1455.
- [49] Rouphael, Y., & Colla, G. (2020). Biostimulants in agriculture. *Frontiers in Plant Science*, 11, 40. <https://doi.org/10.3389/fpls.2020.00040>.
- [50] Sánchez-Rodríguez, E., Rubio-Wilhelmi, M. M., Cervilla, L. M., Blasco, B., Rios, J. J., Rosales, M. A., & Romero, L. (2010). Genotypic differences in some physiological parameters symptomatic for oxidative stress under moderate drought in tomato plants. *Plant Science*, 178(1), 30-40.
- [51] Sathiyabama, M., & Manikandan, A. (2018). Chitosan-silver nanoparticle composite enhances resistance to drought stress in maize plants. *Biocatalysis and Agricultural Biotechnology*, 15, 77-83.
- [52] Scheffé, H. (1953). A method for judging all contrasts in the analysis of variance. *Biometrika*, 40(1-2), 87-104.
- [53] Sharif, R.et.al., (2018). The multifunctional role of chitosan in horticultural crops; a review. *Saudi Journal of Biological Sciences*, 25(4), 709-720.
- [54] Tardieu, F. (2012). Any trait or trait-related allele can confer drought tolerance: just design the right drought scenario. *Journal of Experimental Botany*, 63(1), 25-31.
- [55] Wang, B., Liu, C., & Zhang, D. (2019). Effects of maize organ-specific drought stress response on yields from transcriptome analysis. *BMC Plant Biology*.
- [56] Zayed, M.et.al., (2017). Effect of chitosan and potassium silicate on drought tolerance of maize plants. *Zagazig Journal of Agricultural Research*, 44(4), 1407-1419.
- [57] Zeng, D., & Luo, X. (2012). Physiological effects of chitosan as a biostimulant on plants.

International Journal of Agriculture and Biology, 14(3), 533-538.

- [58] Zhang, Y.et.al.,(2018). Effects of water deficit on stem mechanical strength and its relationship with lignin accumulation in maize. Scientific Reports.
- [59] Zhou, S.et.al.,(2018). How should we model plant responses to drought? An analysis of stomatal and non-stomatal limitations.
- [60] Zlatev, Z. S., & Lidon, F. C. (2012). An overview on drought induced changes in plant growth, water relations and photosynthesis. Emirates Journal of Food and Agriculture, 24(1), 57-72.