Using Salicylic Acid and sodium nitroprusside to mitigate water stress of Canola Plants *(Brassica napus* L.)

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Abstract: The present study aimed to estimate the effects of salicylic acid (400 $mg\ L^{-1}$) and sodium nitroprusside (150 $mg\ L^{-1}$), and their interaction on canola plants under two water stress levels (50, and 100% F.C). This experiment was carried out at the experimental farm, Faculty of Agriculture, Suez Canal University, Ismailia, Egypt during growing season of 2020/2021. The obtained results indicated that increasing water stress levels from 100% to 50% F.C caused significant decrease in all studied growth (except root length) and yield characters, photosynthetic pigments, relative water content (RWC) and some anatomical characters of root and leaves. Also, results showed that salicylic acid and sodium nitroprusside tested treatments statistically improved growth parameters i.e., (root and shoot length, fresh and dry weight and leaf area/plant) and the studied anatomical characters. Conclusively, this study indicates that, foliar application with salicylic acid and sodium nitroprusside and their interaction can decrease the effects of drought stress on growth and yield of canola (*Brassica napus* L.).

***Keywords*:** Canola plant, drought stress, salicylic acid, sodium nitroprusside, anatomy.

INTRODUCTION

Canola (*Brassica napus* L.) belong to the family Brassicaceae. Canola cultivation in Egypt may deliver a chance to overcome the lack of edible oil production in Egypt. Canola can contribute to reducing oil deficiency Consumption gaps. Furthermore, it grows in the northern part of Egypt, New reclaimed soil. And is the second largest oil seed after soybean plant worldwide, producing high-protein meal used for animal feed (FAO, 2018) and (OECD-FAO, 2015). Drought tolerance consists of ability to crop for growth and production under water deficit conditions. A long-term drought stress effects on plant metabolic reactions associates with, plant growth stage, water field capacity of the soil and physiological parts of plant. The agricultural use of water in the world is extra 85% of total water use, moderate to severe drought is a common occurrence, and dry most crops cannot be grown without supplemental irrigation (Cook *et al.,* 2004). Water deficits in plants may lead to physiological defect, like a reduction in photosynthesis (Petropoulos *et al.,* 2008). Water stress effected in plant growth by many morph-physiological that cause defect reduction in nutrient uptake and impaired active transport of photosynthesis (Jaleel *et al.,* 2009). Sodium nitroprusside (SNP) produces nitric oxide (NO), a highly reactive gas and bioactive molecule that plays an essential role in signal transduction in plant stress response (Arasimowicz and Wieczorek, 2007). The effects of NO on different types of cells indicate that NO is an effective antioxidant (Qiao and Fan, 2008). SNP releases NO in a pH-dependent manner that promotes growth of plant and development and delays senescence (Kolberz *et al.,* 2008). The accumulation of NO in plants facilitates auxin-induced lateral root formation (Correa-Aragunde *et al.,* 2006) and adventitious root growth (Tewari *et al.,* 2008). NO produced by SNP has been considered a new member of the phytohormones (Leterrier *et al.,* 2012) and may scavenge reactive oxygen species (ROS) (Laspina *et al.,* 2005). Many studies have shown that this compound can protect plants under stresses and maintain chlorophyll pigments degradation (Raskin, 1992). SNP could improve the effects of water stress and increased chlorophyll (Lichtenthaler, 1978). Salicylic acid (SA) belongs to a group of plant phenolics which has an aromatic ring and natural product of phenylpropanoid metabolism. SA is engaged in plant growth, flower induction and effects on ions uptake (Raskin, 1992). Moreover, that its useful compounds for plants that play an important role in the plant resistance to environmental stresses. This acid is classified among plant growth regulators. Therefore, salicylic acid are endogenous growth regulators of plant that have a main role in physiological processes (Nasibi *et al.,* 2011). The ability of SA to produce defensive effects in plant response to abiotic stress factors (Arivalagan and Somasundaram, 2015). The results of some previous studies shown that exogenous application of SA can aid plant tolerance with many abiotic stresses (Singh and Usha, 2003) and (Farooq *et al.,* 2009). SA plays diverse physiological roles in ethylene biosynthesis, stomatal movements, photosynthesis and enzyme activities (Hayat & Ahmed, 2007). Foliar application of salicylic acid ameliorates the adverse effects of stresses and enhances the restoration of the growth process (Sakhabutdinova *et al.,* 2003). However, the purpose of this study is to reveal the influence of salicylic acid and Sodium nitroprusside as a foliar spray and water stress on some growth characters, yield, physiological and anatomical characters of canola plant (*Brassica napus* L.).

MATERIALS AND METHODS

Two field experiments were carried out during successive winter season 2020/ 21 at the Experimental Farm, Faculty of Agriculture, Suez Canal University, Ismailia, Egypt. The investigation aimed to study the effects of salicylic acid SA (400 $mg\ L^{-1}$) and sodium nitroprusside SNP (150 $mg\ L^{-1}$) The plants were sprayed two times starting from the age of 50 days with one-month intervals among sprayings. Behavior of Canola plant (*Brassica napus* L.) Pectol and Serw 10 under

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water regimes treatments. Recommended irrigations were given to control treatment and soil moisture was maintained to field capacity (100%) until harvest. Drought stress treatments were applied by preventing irrigation to maintain field capacity of 50%. All suggested agricultural practices were followed as and when required. Experimental sub plot consisted of 5 rides 5 m in length and 60 cm in width (5*3 =15m^2).

1- Growth characters measurements:

At 90 days after sowing, ten plants were taken randomly to record: length of (root and shoot), leaves number/ plant, fresh and dry weights of shoot (g), fresh and dry weights of root (g) and number of branches and pods/ plant. yield was measured as seeds weight / plant (g) and oil percentage %.

2- Physiological characters measurements:

a) Photosynthesis pigments content:

The photosynthesis pigments (Chl. *a,* Chl. *b* and carotenoids) were determined in the 3rd leaf from the top of canola after 90 days from sowing. According to (Wettstein, 1957 and Fadl & Sari El- Deen, 1978).

b) Relative water content (RWC) of leaves:

RWC was measured according to (Schonfeld *et al.,* 1988) using the following equation:

$$\text{RWC}\,\% = \frac{\text{Fresh weight - dry weight}}{\text{Turgid weight - dry weight}} \times 100$$

c) Proline content in leaves:

The proline described by (Bates *et al.,* 1973).

d) Seed oil percent (%) using Soxhelt apparatus according to A.O.A.C. (1980).

3- Histological characters:

Some characters of transverse sections (of the third visible leaf from the plant apex were estimated in the season 2020/ 21 and measured such as, thickness of (midrib, secondary xylem, upper epidermis+ palisade tissue and lower epidermis+ spongy tissue) and average number of xylem vessels. Thickness of (epidermis + cortex, vascular bundle and biggest xylem vessles) and number of xylem vessels of roots. All measurements estimated in mμ. Killing and fixation of leaf sample in 70% formalin acetic acid (F.A.A.) solution, dehydration and clearing with ethyl-alcohol and xylene, infiltration and embedding in pure parafine wax (M. P. 56-58o C) were carried out as described by (Nassar & El-Sahhar, 1998). Using a rotary microtome, sections of leaf and root (15μ) were obtained and stained with safranin and light green. Sections, in such cases were microscopically examined and analyzed with the image processing program Image. Anatomical examination and measurements were achieved using a Leica light Research Microscope model PN: DM 500/13613210 supplied with a digital camera.

4- Statistical analysis:

This study was statistical analyzed by using appropriate analysis of variance (ANOVA) for three factorial experiments with randomized complete block design (R. C. B. D) with three replications. Statistical analysis was done using the COSTAT program for Window, version 6.311 (Cohort Software, Berkeley, CA, USA). The differences between means were compared using the least significant difference test (L.S.D) at 5% levels according to (Snedecor and Cochran, 1990).

RESULTS AND DISCUSSION

The impact of drought and foliar spraying with salicylic acid (SA), sodium nitroprusside (SNP) as well as their interaction on growth characters of canola cultivars Pectol and Serw10 were recorded in Table 1 and 2 during season 2020/21. Data in Table 1 showed that increasing drought stress (water regime) from 100% (434 g, 61.3 g, 19.2, and 99.6 cm) to 50% F.C (354 g, 58.3 g, 16.5, 81.2 cm) significantly decreased both fresh and dry weights of shoot/plant (FW, DW) as well as number of leaves/ plant and shoot length, respectively. But contrary trend found with root length. Regarding the cultivar effect, it is clearly that Serw10 cv. significantly exceeded Pectol cv. in root length, leaves number/ plant and shoot dry weight. While Pectol cv. surpassed Serw10 cv. in length and fresh weight of shoot/ plant. As is evident from the data in Table 1 indicated that the interaction between SNP and SA treatment increased both root and shoot and shoot length compared with control and other treatments. The highest values of root and shoot length recorded 43.3 cm and 112 cm under 50% and 100% F.C, respectively. The SNP treatment significantly exceeded in number of leaves/ plant, fresh and dry weights of shoot this is under 100% F.C (27, 562 gm and 112), respectively compared to control and other treatments. Similarity trend with (Zamani *et al.,* 2014) found that SNP increased length of shoot and root, wet and dry weight of stem. In addition, Eisa. and Seham (2016) reported that SNP improved and overcome the negative effects of water stress on the morphological characters (Plant height (cm), No. of leaves/ Plant and No. of branches/ plant). Data in Table 2 reveal the values of dry weights of root/ plant, branches and pods numbers/ plant and seeds weight/ plant (g) of two tested cultivars of canola (Serw10 and Pectol) with two water regimes and four treatments as well as their interactions. All characters decreased by increasing water stress from 100 % (23.5 g, 24.0, 247 and 68.9) to 50% F.C (22.0 g, 22.0, 240 and 48.1), respectively. Shortage of water stress leads to reduce the seed quality by producing small sized seeds (Alqudah *et al*., 2010). Fahad *et al.,* (2017) observed that under water stress, the enzymatic activities of plants are diminished, that eventually lead to decrease the yield and quality of oilseed crops. It is clearly shown from Table 2 that the weight of fresh and dry roots were increased as a result of foliar spraying of SNP with two water regimes (50% and 100%) in both treated canola cultivars compared with control and other treatments. On the other hand, branches and pods numbers/ plant and seeds weight/ plant (g) recorded height values as result to foliar spraying with SA treatment at 50% and 100% F.C of both studied cultivars compared with other treatments. (Zamani *et al.,* 2014) showed that SNP increased fresh and dry weight of root. In addition, Eisa. and Seham (2016) reported that SNP improved and overcome the adverse effects of water stress on the yield characters (No. of seeds/ pod, No. of pods/ plant, Weight of seeds/ pod (g), Weight of seeds/ plant (g) and Weight of 100 seeds (g). As to the cultivar action, Pectol cv. (90.1 g, 24.9 and 61.1g) significantly exceeded Serw10 cv. (82.4 g, 20.8 and 55.9 g) for root fresh weight/ plant (g), branches number/ plant and seeds weight/ plant (g), respectively.

Table (1): Effect of SA, SNP and their interaction under drought stress treatments of canola cvs. "Pectol and Serw10" at 90 days from sowing during 2020/21 season

Treatments / Data			Root length (cm)	Shoot length (cm)	Leaves number/ plant	Shoot fresh weight/ plant (g)	Shoot dry weight/ plant (g)
Variety							
Pactol			26.5	91.9	16.5	407	55.4
Serw 10			31.9	88.9	19.2	381	64.2
Days							
100 % F.C			28.0	99.6	19.2	434	61.3
50 % F.C			30.4	81.2	16.5	354	58.3
Treatments							
Con			29.3	88.3	17.0	434	62.0
SNP			26.9	78.9	18.7	439	66.6
SA			27.5	96.5	17.4	392	57.8
SNP+SA			33.2	97.9	18.3	310	52.8
Interaction							
Pectol	**100 % F.C**	**Con**	28.7	104	15.0	525	54.7
		SNP	21.3	87.7	21.0	562	64.7
		SA	21.7	110	17.0	460	52.0
		SNP+SA	29.0	112	15.0	300	59.0
	50 % F.C	**Con**	28.0	79.7	14.0	369	48.7
		SNP	33.3	64.0	17.7	506	64.7
		SA	33.0	85.0	17.0	294	47.7
		SNP+SA	37.0	92.7	15.0	240	51.7
Serw 10	**100 % F.C**	**Con**	27.3	108	20.0	360	68.7
		SNP	22.0	86.0	27.0	515	112
		SA	20.3	106	20.7	406	87.7
		SNP+SA	29.0	108	19.0	430	65.3
	50 % F.C	**Con**	41.3	61.3	17.0	345	50.0
		SNP	31.0	78.0	19.0	384	51.3
		SA	41.0	75.3	15.0	332	44.0
		SNP+SA	43.3	88.7	16.0	272	35.0
ANOVA		**Df**	P value 0.05				
V		1	<0.001**	ns	Ns	<0.001**	<0.001**
D		1	<0.001**	ns	Ns	<0.001**	<0.001**
T		3	<0.001**	ns	Ns	<0.001**	<0.001**
V×D		1	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**
V×T		3	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**
D×T		3	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**
V×D×T		3	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**

Note: F.C (Field Capacity), SA (Salicylic acid), SNP (Sodium nitroprusside), Con (Control).

Table (2): Effect of SA, SNP and their interaction under drought stress treatments of canola cvs. “Pectol and Serw10” at 90 days from sowing during 2020/21 season

Treatments/ Data			Root fresh weight/ plant (g)	Root dry weight (g)	Branches number/plant	Pods number /plant	Seeds weight/plant (g)
Varieties							
Pactol			90.1	20.9	24.9	241	61.1
Serw 10			82.4	24.8	20.8	246	55.9
Days							
100 % F.C			86.3	23.5	24.0	247	68.9
50 % F.C			86.3	22.3	22.0	240	48.1
Treatments							
Con			74.0	21.4	21.6	261.3	56.0
SNP			101	25.5	20.4	217.3	70.3
SA			92.3	20.8	25.3	234.5	54.3
SNP+SA			77.7	23.8	24.2	260.4	53.5
Interaction							
Pectol	**100 % F.C**	**Con**	90.0	23.0	25.0	295	77.0
		SNP	119	29.0	25.0	204	50.0
		SA	95.0	23.0	32.0	384	109
		SNP+SA	97.0	26.0	31.0	205	62.0
	50 % F.C	**Con**	76.0	18.0	21.3	200	45.0
		SNP	90.0	19.0	16.7	200	47.0
		SA	85.0	12.0	26.0	275	55.0
		SNP+SA	68.7	17.0	22.0	165	44.0
Serw10	**100 % F.C**	**Con**	67.0	31.7	22.0	295	52.0
		SNP	103	33.0	23.0	275	67.0
		SA	94.0	32.0	27.0	295	78.0
		SNP+SA	88.0	25.0	14.7	205	56.0
	50 % F.C	**Con**	63.0	13.7	18.0	255	50.0
		SNP	97.0	25.0	17.0	190	47.0
		SA	90.0	15.0	18.0	273	56.0
		SNP+SA	57.0	24.0	17.0	178	41.0
ANOVA		**Df**	**P value 0.05**				
V		1	<0.001**	<0.001**	0.04	Ns	<0.001**
D		1	Ns	Ns	Ns	Ns	<0.001**
T		3	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**
V×D		1	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**
V×T		3	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**
D×T		3	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**
D×T		3	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**

Note: F.C (Field Capacity), SA (Salicylic acid), SNP (Sodium nitroprusside), Con (Control).

while Serw10 cv. (246) significantly exceeded Pectol (241) for root dry weight (g) pods number/ plant. Concerning with cultivar effect, Table 3 and Fig 1 "b" cleared that difference between Pectol and Serw10 cultivars was significantly for proline and relative water contents (RWC) where Serw 10 cv. superior to the other cultivar for oil and RWC percentage (45.9 and 68.4 %), respectively. While Pectol cv. recorded highest value for prolin content (7.1 mg/100gm F.W). The adaptive osmolyte, such as proline control actions like regulating osmotic acts, protecting intercellular structure and decreased oxidative damages producing free radicals respond to drought and salinity stresses (De Lacerda *et al.*, 2005). Proline is the most popular solution that widely has various application associated with drought (Sudhakar *et al.,* 1993). Increasing drought stress decreased oil and RWC percentages while, proline content increased with increasing drought levels. The reduction in oil content has been observed under water deficient conditions reported by Maclagan (1993). Serraj and Sinclair (2002) revealed that the increasing level of proline (Pro) content in many drought-induced plant species have been associated with the decrease in the protein content and the increase in proteolytic activation, resulting in an increase in the total soluble nitrogen. Drought might decrease the oil content and compositions in plants (Bagheri *et al*., 2012), due to drought conditions often alter the composition and biosynthesis process of fatty acids leading to the reduction of oil yield and composition (Baldini *et al*., 2000). In relation to the SA, SNP and their interaction effect, Table 3 illustrated that salicylic acid (SA) treatment superior to the other treatments for oil percentage under two water regimes (50 and 100% F.C) in both cultivars. EL Sabagh *et al.*, (2019) observed that the application of salicylic acid (SA) in combination with irrigation intervals achieved superior yield of canola, as well as significant increase in protein and oil content of canola. (Keshavarz *et al*.,2016) illustrated that the application of SA has useful effects on the biochemical characters of Brassica napus cultivars. Therefore, it may be effective for the improvement of plant growth. The RWC % and proline content recorded the highest values with sodium nitroprusside (SNP) treatment although with two studied cultivars under drought stress compared with control and other treatments.

Table (3): Effect of SA, SNP and their interaction under drought stress treatments of canola cvs. "Pectol and Serw10" at 90 days from sowing during 2020/21 season

Treatments / Data			seed yield / feddan (kg)	oil percentage %	oil yield /feddan(kg)	RWC%
Varieties						
Pactol			2139	45.8	46.5	63.3
Serw 10			1956	45.9	42.6	68.4
Days						
100 % F.C			2411	46.7	51.7	65.9
50 % F.C			1684	45.0	37.4	65.8
Treatments						
Con			1960	45.7	42.8	69.0
SNP			2459	46.0	53.2	70.9
SA			1899	46.0	41.6	55.9
SNP+SA			1873	45.8	40.7	67.4
Interaction						
Pectol	**5 DAYS**	**Con**	2695	46.6	57.8	64.1
		SNP	3815	47.0	81.2	77.3
		SA	1750	48.0	36.5	52.1
		SNP+SA	2170	47.0	46.2	71.1
	10 DAYS	**Con**	1575	44.0	35.8	62.2
		SNP	1645	44.0	35.8	71.0
		SA	1540	46.0	35.0	45.1
		SNP+SA	1925	44.0	43.8	63.6
Serw 10	**5 DAYS**	**Con**	1820	46.0	39.6	72.0
		SNP	2730	46.0	59.4	77.5
		SA	2345	48.0	52.1	72.0
		SNP+SA	1960	46.0	40.8	63.4
	10 DAYS	**Con**	1750	45.0	38.0	72.3
		SNP	1645	45.0	36.6	72.3
		SA	1960	46.0	42.6	63.0
		SNP+SA	1435	45.0	31.9	63.0
ANOVA	**Df**		**P value 0.05**			
V	1		<0.001**	Ns	0.04*	0.02**
D	1		<0.001**	Ns	<0.001**	ns
T	3		<0.001**	Ns	<0.001**	<0.001**
V×D	1		<0.001**	<0.001**	<0.001**	<0.001**
V×T	3		<0.001**	<0.001**	<0.001**	<0.001**
D×T	3		<0.001**	<0.001**	<0.001**	<0.001**
V×D×T	3		<0.001**	<0.001**	<0.001**	<0.001**

Note: F.C (Field Capacity), SA (Salicylic acid), SNP (Sodium nitroprusside), Con (Control).

Photosynthetic pigments:

Data in Fig 1 (A, C and D) show the content of different photosynthetic pigments viz, chlorophyll *a* and *b* and carotenoids in the two cultivars of canola as affected by two water regimes which foliar sprayed with SA, SNP and their interaction. Results signify that concentrations of three components in the leaves of two studied cultivars were decreased as a result of drought stress. With regard to the chlorophyll *b* and carotenoids, Pectol cv. proved to be significantly superior to Serw10 cv. concerning the chlorophyll *a* there are no significant differences between cultivars. Foliar spraying with SA, SNP and interactions effect, were shows in Fig 1. reported that the SNP and SA with Pectol cv. under two water regimes increased chlorophyll a content compared with control and other treatments. While SA treatment increased chlorophyll *a* content with Serw10 cv. under 100% F.C. Enhancement the pigments content of chlorophyll and carotenoids by modifying the activity of some important enzymes are other roles of SA (Ruelland *et al.,* 2016). Moreover, Carotenoids recorded highest values with SA treatment under two water regimes with both cultivars. These results agreed with those reported by (Zamani *et al.,* 2014) who found that SA increased the content of proline. Moreover, the effect of SA on growth and some morphological characteristics of plant showed SA improved physiological characters and photosynthetic its resistance to severe conditions under stress (Sudhakar *et al.,* 1993). The chlorophyll has a reduction under stress (Amin 2008). Reducing chlorophyll concentration is an important and efficient agent in photosynthesis and also increasing drought level cause to accelerate the injuries of drought. Hence, decreasing growing is related to a fall of photosynthesis rate (Cengiz *et al*., 2013).

Anatomical characters: -

-Root anatomy:

Data in Table 4 and plate 1, 2 pointed that out the xylem vessels number, thickness of (biggest xylem vessels and epidermis+ cortex) were significantly decreased as a result of increasing the water regimes. On the other hand, an opposite trend was shown with secondary xylem was increased with increasing drought stress. Serw 10 cv. proved to exceed significantly those obtained with the cultivar Pectol cv. for thickness of (biggest xylem vessels, epidermis+ cortex and secondary xylem). El- Hadidi *et al*. (2007) who showed that number of secondary xylem, thickness of both secondary xylem and phloem tissues, were decreased with increasing water stress levels, meanwhile thickness of cortex was increased. stem diameter may be decreased by reduction in vascular tissue resulted from inhibition of cambial cell activity and/or reduced DNA content resulted in reduced cell division and expansion (Wignarajah *et al*., 1975). As for the effect of foliar spraying with SA, SNP and their interaction that SNP+SA treatment increased all the studied anatomical characters of root under both water regimes with Pectol cv. and Serw 10 cv. compared with control and other treatments.

-Leaf anatomy:

Table 5 and plate 3, 4 clearly shown that the thickness of (lower epidermis+ spongy tissue, main vascular bundle, upper epidermis+ palisade tissue and midrib) and number of xylem vessles/ main vascular bundle were decreased by increasing the water regimes (from 100 to 50% F.C). These results are in harmony with the finding of Akram et al., (2016) reported that water stress caused a reduction in the leaf vascular bundle area, leaf midrib thickness, leaf parenchyma cell area and the number of vascular bundles while water stress increased leaf epidermis thickness. The cultivar effect, Serw10 cv. significantly excelled Pectol cv. for all studied anatomical characters of leaves. As a result of foliar spraying with SA treatment was increased thickness of lower epidermis+ spongy tissue and number of xylem vessles/ main vascular bundle compared with control and other treatments for Pectol and Serw10 cultivars under both water regimes. Thickness of (main vascular and midrib) increased by foliar SNP treatment for both cultivars were studied under 50% and 100% F.C. thickness of upper epidermis + palisade tissue was significantly increased as a result of foliar spraying with interaction between SA+SNP treatment as compared with the control and other treatments. Farouk and Arafa (2018) reported that SNP superposed thickness of midrib region, length and width of the main vascular bundle, increased leaf blade thickness, palisade parenchyma thickness and spongy parenchyma thickness.

CONCLUSION

Drought is harmful to canola plants. The 50% FC used is enough to cause damages in tissues of plants and therefore in their physiology. The use of SA and SNP is an alternative to perfect the water stress generated, and in the case of this study, especially 400 and 150 mg/L^{-1} respectively, effective to mitigate the damage to the most of growth, physiological and anatomical characters under this study.

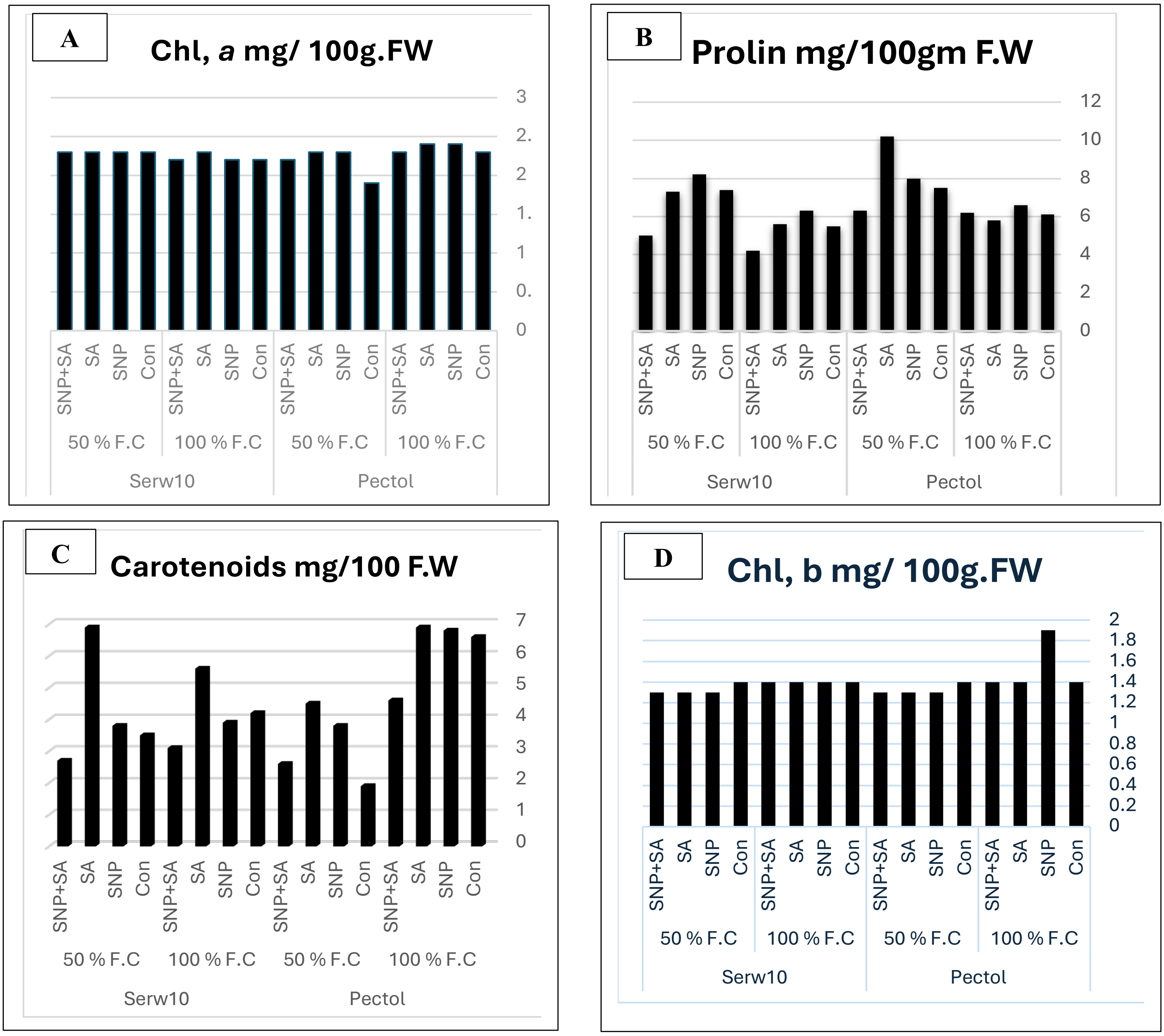

Fig. (1) Effect of SA and SNP and their interaction under drought stress treatments on Chl, *a* and *b*, Carotenoids and Prolin of canola cvs. "Pectol and Serw10" at 90 days from sowing during 2020/21 season.

Table (4): Effect of SA and SNP and their interaction under drought stress treatments on root anatomy of canola cvs. "Pectol and Serw10" at 90 days from sowing during 2020/21 season

Treatment / Data			Xylem vessles number of root	Thickness of biggest xylem vessles in root (µm)	Epidermis + cortex thickness of root (µm)	Secondary xylem thikness of root (µm)
Varieties						
Pactol			68.9	79.4	341	1109
Serw 10			65.6	90.7	369	1224
Days						
100 % F.C			70.0	89.8	359	1128
50 % F.C			64.5	80.4	350	1206
Treatments						
Con			73.1	82.5	350	1137
SNP			65.3	87.8	356	1144
SA			53.5	79.0	307	1100
SNP+SA			77.1	90.9	406	1285
Interaction						
Pectol	**5 DAYS**	**Con**	62.0	100	325	975
		SNP	59.0	100	350	1225
		SA	57.0	75.0	302	1175
		SNP+SA	74.0	105	475	1225
	10 DAYS	**Con**	77.0	50.0	274	950
		SNP	66.0	50.0	325	1125
		SA	66.0	75.0	300	1001
		SNP+SA	90.0	80.0	375	1197
Serw 10	**5 DAYS**	**Con**	61.3	100	400	1370
		SNP	60.0	96.0	375	1125
		SA	41.0	103	325	1125
		SNP+SA	73.0	109	400	1625
	10 DAYS	**Con**	80.0	80.0	375	1000
		SNP	76.0	75.0	374	1100
		SA	50.0	63.0	300	1100
		SNP+SA	83.0	100	400	1350
ANOVA	**Df**		**P value 0.05**			
V	1		NS	<0.001**	<0.001**	<0.001**
D	1		0.02**	0.03**	0.04*	<0.001**
T	3		<0.001**	<0.001**	<0.001**	<0.001**
V×D	1		<0.001**	<0.001**	<0.001**	<0.001**
V×T	3		<0.001**	<0.001**	<0.001**	<0.001**
D×T	3		<0.001**	<0.001**	<0.001**	<0.001**
V×D×T	3		<0.001**	<0.001**	<0.001**	<0.001**

Note: F.C (Field Capacity), SA (Salicylic acid), SNP (Sodium nitroprusside), Con (Control)

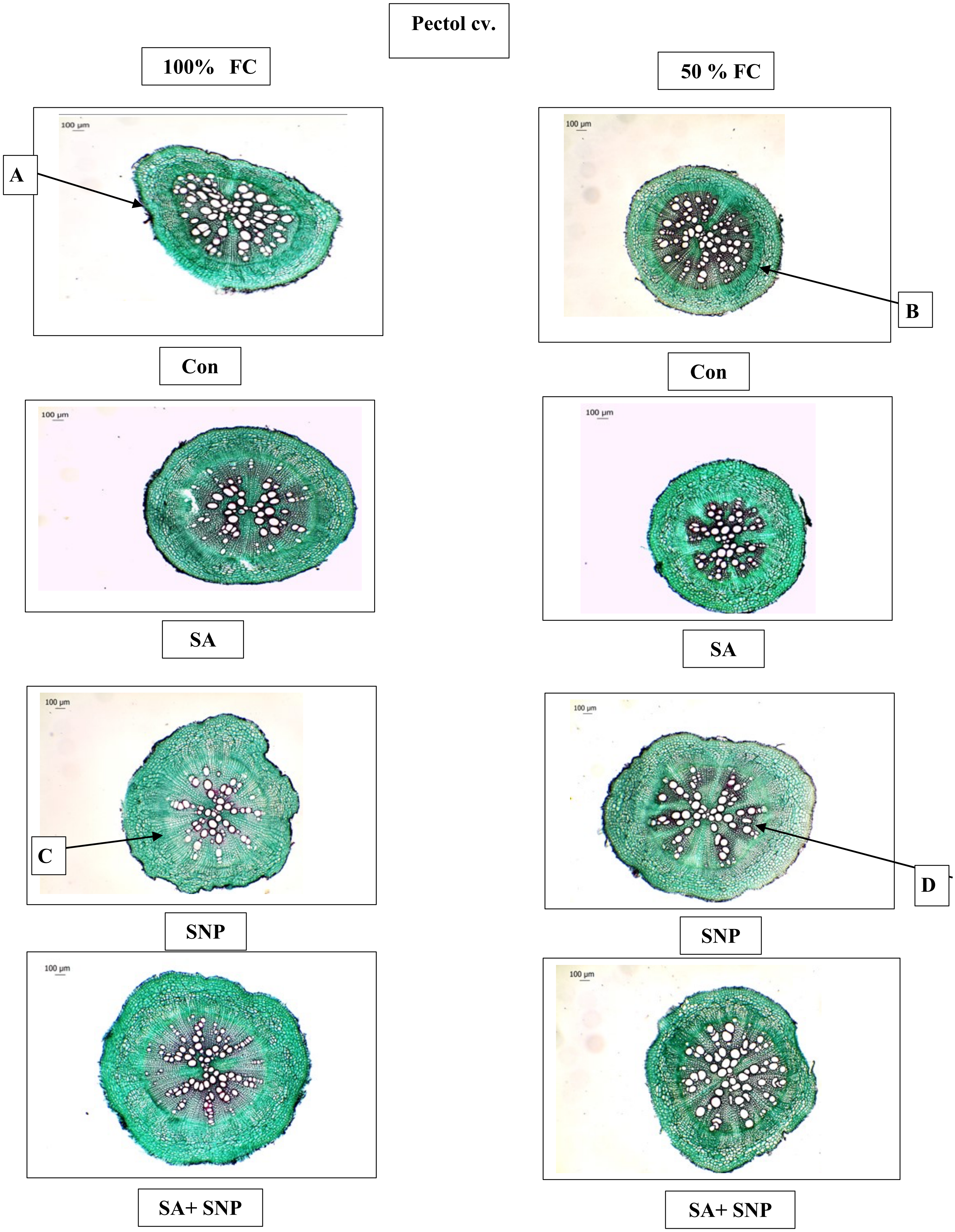

Plate 1. Cross sections of root of canola (Pectol cv.) under SA, SNP, their interaction levels and FC% treatments during 2020/2021 season. A: Epidermis, B: Cortex, C: secondary xylem, and D: xylem vessel. Bar=100µm 4X.

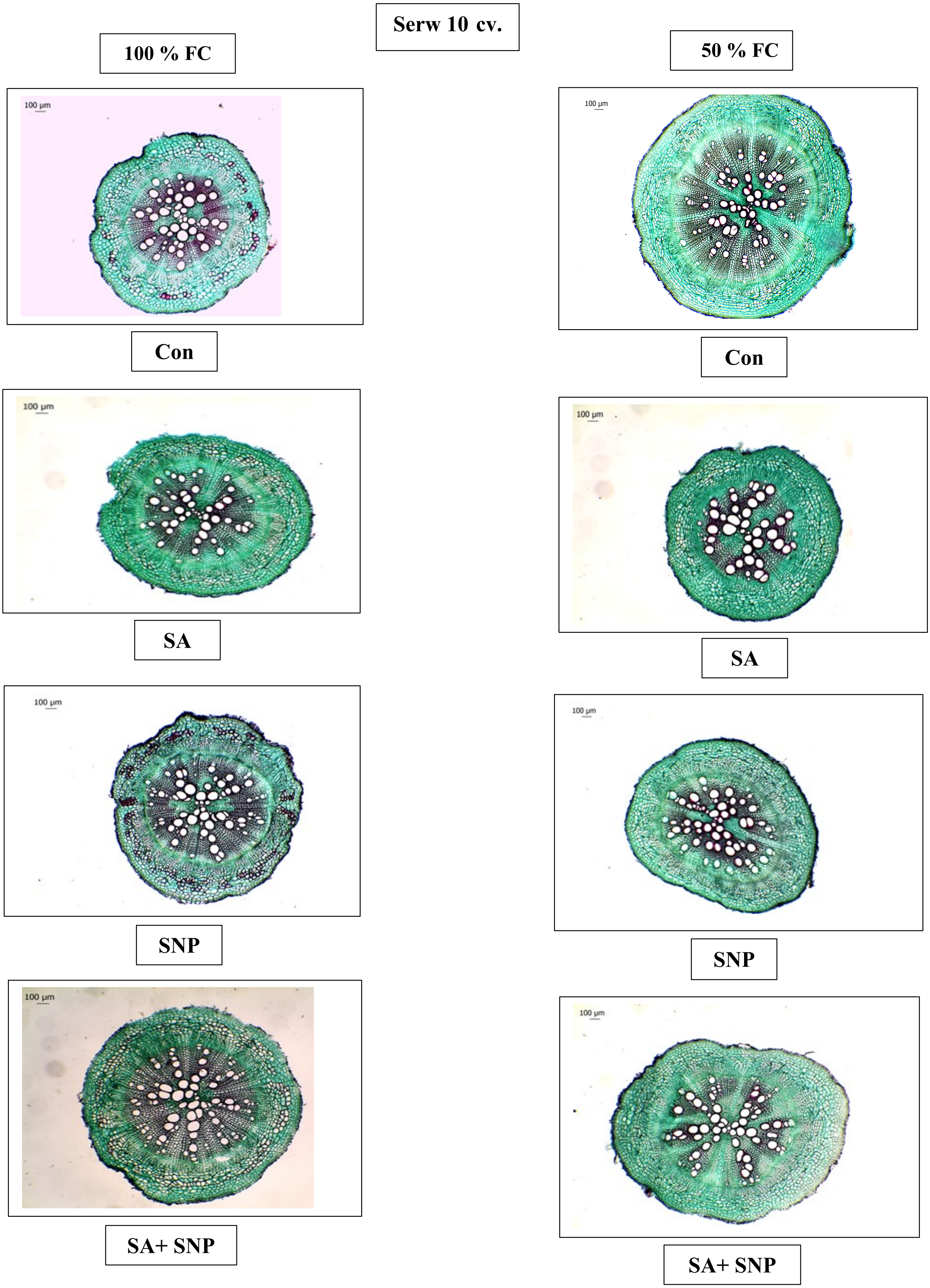

Plate 2. Cross sections of root of canola (Serw10 cv.) under SA, SNP, their interaction levels and FC% treatments during 2020/2021 season. Bar=100µm. 4X

Table (5): Effect of SA, SNP and their interaction under drought stress treatments on leaf anatomy of canola cvs. "Pectol and Serw10" at 90 days from sowing during 2020/21 season

Treatment / Data			Midrib thickness (µm)	Thickness of main v.b (µm)	Thickness of upper epidermisn+palisde tissue (µm)	Thickness of lower epidermisn+spongy tissue (µm)	No. of xylem vessles/ main v.b in leaf
Varieties							
Pactol			644	244	204	145	22.8
Serw 10			782	301	214	147	33.5
Days							
100 % F.C			774	287	211	150	28.8
50 % F.C			652	259	208	142	27.5
Treatments							
Con			665	262	208	143	24.7
SNP			792	300	187	137	24.2
SA			750	265	220	173	34.7
SNP+SA			646	264	223	131	29.0
Interaction							
Pectol	**5 DAYS**	**Con**	660	229	229	140	14.3
		SNP	974	374	226	150	16.0
		SA	770	280	220	230	29.0
		SNP+SA	570	220	250	129	19.0
	10 DAYS	**Con**	560	210	170	150	18.0
		SNP	610	230	170	100	26.7
		SA	580	210	169	150	31.3
		SNP+SA	430	200	200	110	28.0
Serw 10	**5 DAYS**	**Con**	820	310	220	160	31.0
		SNP	1074	374	200	99.7	24.0
		SA	909	320	250	160	34.0
		SNP+SA	974	325	251	125	33.0
	10 DAYS	**Con**	620	270	190	150	35.0
		SNP	710	300	150	150	30.0
		SA	540	250	220	170	45.3
		SNP+SA	610	260	230	160	35.0
ANOVA	**Df**		**P value 0.05**				
V	1		<0.001**	<0.001**	<0.001**	Ns	<0.001**
D	1		<0.001**	<0.001**	Ns	<0.001**	Ns
T	3		<0.001**	<0.001**	<0.001**	<0.001**	<0.001**
V×D	1		<0.001**	<0.001**	<0.001**	<0.001**	<0.001**
V×T	3		<0.001**	<0.001**	<0.001**	<0.001**	<0.001**
D×T	3		<0.001**	<0.001**	<0.001**	<0.001**	<0.001**
V×D×T	3		<0.001**	<0.001**	<0.001**	<0.001**	<0.001**

Note: F.C (Field Capacity), SA (Salicylic acid), SNP (Sodium nitroprusside), Con (Control).

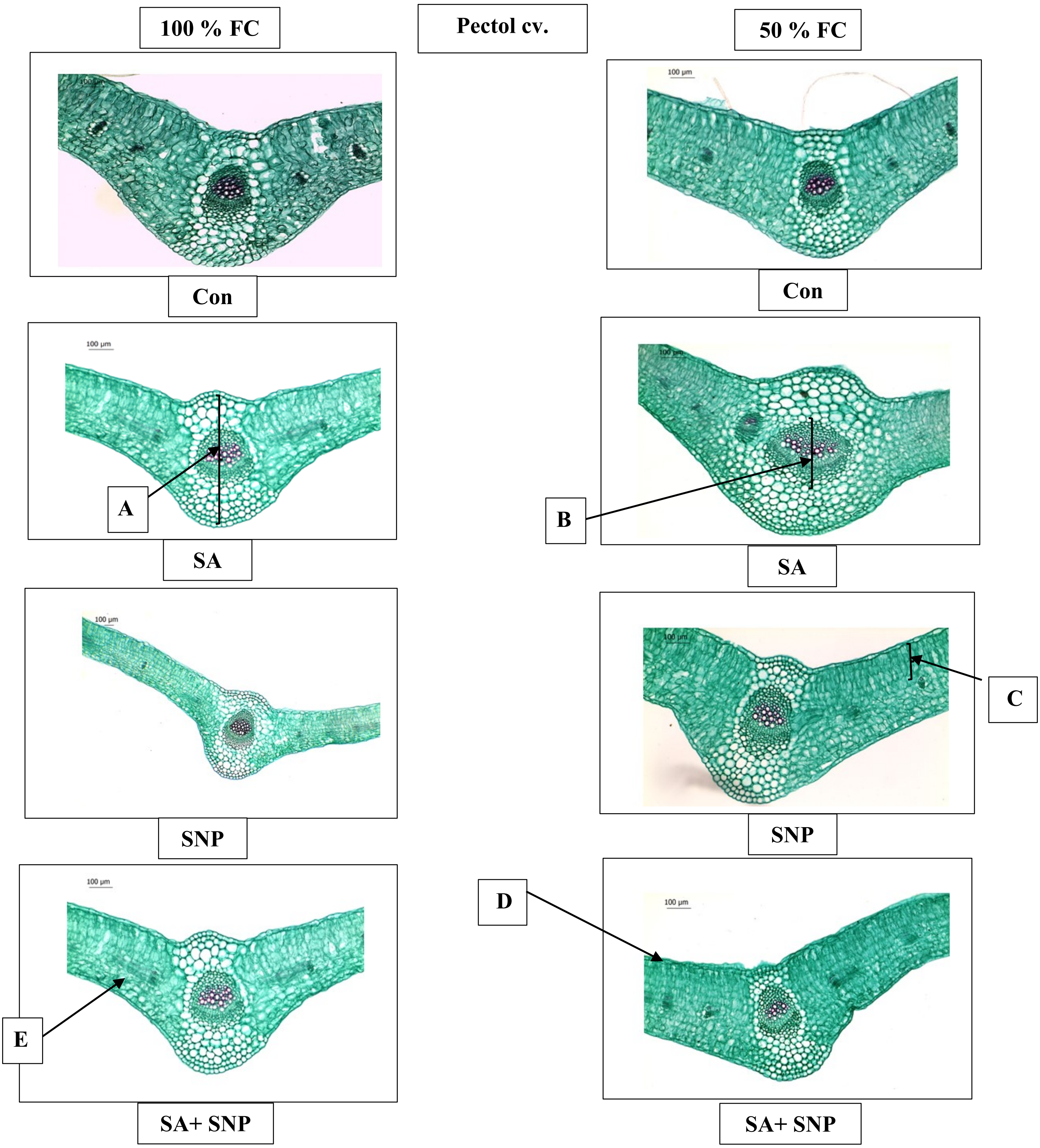

Plate 3. Cross sections of leaf of canola (Pectol cv.) under SA, SNP, their interaction levels and FC% treatments during 2020/2021 season. A: Midrib, B: Main vascular bundle, C: Palisad tissue, D: Upper epidermis and E: Spongy tissue. Bar=100µm. 10X

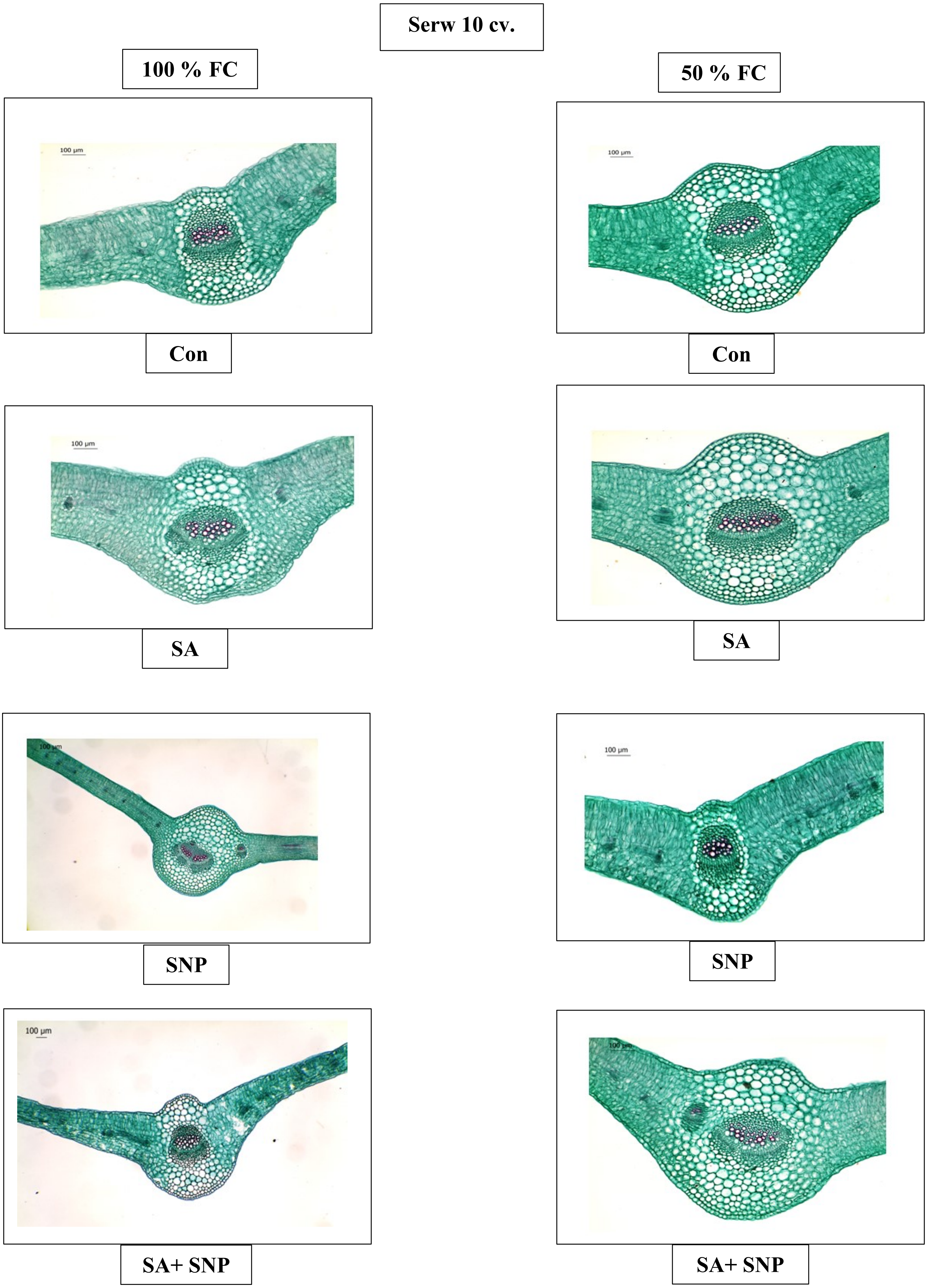

Plate 4. Cross sections of leaf of canola (Serw 10 cv.) under SA, SNP, their interaction levels and FC% treatments during 2020/2021 season.

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استخدام حمض السالسيلك و نيتروبروسيد الصوديوم للتخفيف من الاجهاد المائى لنباتات الكانولا (*Brassica napus* L.)

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المستلخص: تهدف هذه الدراسة الى تقدير تأثير حمض السالسيليك بتركيز (400 مليجرام /لتر) ونيتروبروسيد الصوديوم بتركيز (150 مليجرام/ لتر) وتفاعلهم على نبات الكانولا تحت مستويين من الاجهاد المائى (50 و100 % من السعة الحقلية). وقد اجريت هذه التجربة بمزرعة كلية الزراعة جامعة قناة السويس بالاسماعيلية خلال موسم 2021/2020. وقد اكدت النتائج ان بزيادة مستويات الاجهاد المائى من 100% الى 50% تسبب فى نقص كل صفات النمو تحت الدراسة ماعدا صفة طول الجذر وايضا نقص فى الصفات المحصولية تحت الدراسة وصبغات البناء الضوئى ومحتوى الماء المرتبط وبعض الصفات التشريحية للجذر والاوراق. ايضا اظهرت النتائج معاملة نبات الكانولا بحمض السالسيليك ونيتروبروسيد الصوديوم تحسنا فى صفات النمو والصفات التشريحية. ايضا معاملة النباتات بحمض السالسيليك ونيتروبروسيد الصوديوم والتفاعل بينهم اظهرت وبشكل واضح تقليل أثر الاجهاد المائى على النمو والحصاد لنباتات الكانولا.

الكلمات المفتاحية: نبات الكانولا، اجهاد الجفاف، حمض السالسيلك، نيتروبروسيد الصوديوم، تشريح