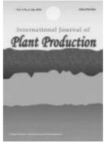

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Salt stress and transplant time in snap bean: growth and productive behaviour

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Abstract

High quality water is less available for agriculture and thus farmers often use saline water, that affects crop growth and yield. Snap bean (*Phaseolus vulgaris*) is sensitive to soil and water salinity, and also to heat stress. The aim of this research is to evaluate if a postponed transplant (high temperature stress) of snap bean can influence growth and yield under saline conditions. Snap bean 'Bolero' was irrigated with water at 5 salt levels (0.7, 3.0, 6.0, 9.0 and 12.0 dS m^{-1}) in factorial combination with two transplant time: ordinary (first week of June=OT) and postponed (first week of July=PT). The percentage of plant survival and plant growth were measured throughout the whole growth cycles. Irrigations with saline water resulted in increased values of soil salinity. The PT cycle was shorter than OT cycle and fewer accumulated GDDs were necessary for ripening (658.7 °C vs. 790.5 of OT cycle). Saline treatments caused a decrease of survival percentage, growth, LA and yield. Also high temperature stress determined a decrease of growth and yield, especially of number of marketable pods per square meter, not compensated by a higher plant density. Therefore, it doesn't seem favourable to postpone the transplant of snap bean under saline conditions.

Keywords: Salt-tolerance; Transplant time; High temperature stress; Stress mitigation; Snap bean.

Introduction

In past years the principal objective of agricultural research was to reach higher yield; therefore the use of high energetic inputs (manuring, irrigation, greenhouses, etc.) increased. But, because water is not an unlimited resource, also at the Fifth World Water Forum of Istanbul it was discussed the possibility to product more yield with less water. The data reported in that Forum showed that Agriculture accounts for 70% of all freshwater withdrawals compared to 20% for industry and 10% for municipal and domestic use, although in Africa and Asia more than 80% of water is for agriculture compared to less than 40% in Europe and North America (FAO, 2009).

Besides, the world population growth rapidly in urban areas, therefore there is always less water for farming, and at the same time, water quality is undergoing rapid decline (FAO, 2002).

The use of saline water is one of the main sources of soil salinity, because in irrigated lands leaching is inadequate, leading to the accumulation of salts in the root zone (Adiku et al., 2001).

At the same way, damages of saline waters are greater for crops cultivated under rainout-shelter, because there is a continuous and progressive accumulation of salts in the soil, without the possibility of a natural leaching due to rainfalls.

The data of FAO (2002) reported that about 20-30 million of hectares of irrigated soils are severely affected by salt accumulation and for this problem 0.25-0.5 million of hectares per year can not be used for food production.

Many researches were carried out on saline soil or water with high concentration of NaCl and many crops were tested: tomato (Mori et al., 2008; Di Mola et al., 2004; De Pascale et al, 2003), lettuce (Mori et al., 2004; De Pascale and Barbieri, 1995), sunflower (Flagella et al., 2004), legume crops (De Pascale et al., 1997; Longstreth and Nobel, 1979), potato (Patel et al., 2001), etc.

However, actually the research shows a great interest for legume crops, since the rising cost of nitrogen fertilizer; in fact these crops are well known for the biological nitrogen fixation and for the favourable effects of N balance of the cropping systems.

The legume crops have an elevated sensibility to the salinity (Maas and Hoffman, 1977) but the yield loss rate shows a high intra-and inter-specific variability (Shannon and Grieve, 1999). Particularly, bean (*Phaseolus vulgaris*) is a crop sensitive to salt with total yield loss at 6.3 dS m^{-1} for the soil salinity (measured in a saturation extract) and at 4.2 dS m^{-1} for water salinity (Flagella et al., 1999).

Besides, as known, salt tolerance varies with the phenophase: seed germination and early seedling growth are generally the most sensitive stages to salt stress, since plant salt tolerance usually increases with plant ontogeny (Foolad, 2004). Particularly, snap bean seems more sensitive in the growth and filling pod phases (Cucci et al., 2000).

The salt effects on plants are morphological, such as growth and yield losses (Mori et al., 2008; De Pascale et al., 1997), leaf extension decrease (Curtis and Lauchli, 1986), and physiological, such as photosynthesis reduction, stomatal and mesophyll resistance increase (Longstreth and Nobel, 1979), changes in water potentials (De Pascale et al., 1999; De Pascale et al., 1997; Boyer and Meyer, 1980).

It is known that the severity of salinity response is also mediated by environmental interactions such as relative humidity, temperature, radiation and air pollution (Shannon et al., 1994; Maggio et al., 2009). Helal and Mengel (1981) observed that high temperatures together with low relative humidity, increase the evapotranspiration and reduce plants tolerance to the salinity, due to increase of water flow and therefore of the salts accumulation in the root zone.

In particular, the temperature influences crop tolerance to salinity more than relative humidity (Flagella et al., 1999).

But heat stress can be an important limiting factor in distribution, adaptability, and productivity of wild and cultivated plants (Omae et al., 2006).

Short exposure of plants to high temperatures during seed filling can accelerate senescence, reduce seed set, seed weight and yield (Siddique et al., 1999), because plants tend to divert resources to cope heat stress thus limiting photosynthates availability for the reproductive development (Wahid et al., 2007). Another effect of heat stress in many species is sterility when heat is imposed immediately before or during anthesis. Pulse legumes are particularly sensitive to heat stress at the bloom stage; only a few days of exposure to high temperatures (30-35 °C) can cause heavy yield losses through flower drop or pod abortion (Siddique et al., 1999).

Different phenological stages differ in their sensitivity to high temperature; however, this depends on species and genotype as there are great inter and intra-specific variations (Wollenweber et al., 2003; Howarth, 2005).

Reproductive phases most sensitive to high temperature are gametogenesis (8-9 days before anthesis) and fertilization (1-3 days after anthesis) in various plants (Foolad, 2005).

In temperate and tropical lowlands, heat susceptibility is a cause of yield loss in common bean, *Phaseolus vulgaris* (Rainey and Griffiths, 2005).

Snap bean yield is affected by high temperatures due to lack of pollination and the early abscission of flowers and young pods (Omae et al., 2005a; Tsukaghuci et al., 2003; Suzuki et al., 2001; Nakano et al., 1998; Nakano et al., 2000; Anthony et al., 1980).

Also in maize, high temperature reduces the pollen viability and silk receptivity of corn resulting in poor seed set and reduced yield (Tassawar et al., 2007; Giaveno e Ferrero, 2003). A short period of exposure to high temperature (>35 °C) can drastically reduce wheat yield (Randall and Moss, 1990; Hawker and Jenner, 1993; Stone and Nicolas, 1994). Efforts have been made to understand plant response to gradual and sudden increase in temperatures (Stone and Nicolas, 1995), and it has been noted that gradual rise in daily maximum temperature inflicts relatively less damage in comparison to a sudden temperature rise (Rane et al., 2004).

Internal plant status may also be associated with heat tolerance under non-water-stressed conditions (Omae et al., 2005b; Omae et al., 2005c; Kumar et al., 2005).

Drought stress induces genotypic variation of shoot biomass accumulation, pod and seed number, and biomass partitioning index (Rigoberto et al., 2004; Porfirio and James, 1998). Heat stress may also affect morphological characters, changing yield and yield components in snap bean (Omae et al., 2006).

Relatively few studies were carried out about the combined effect of salinity and heat stress. Bustan et al. (2004) showed that combined heat wave and salt stress, if it occurs at 40-60 day after emergency, causes irreversible canopy impairments that may lead to significant reduction in tuber yield in potato crops.

The aim of this research has been to evaluate the effects of different salt levels of irrigation waters on the agronomic behaviour of snap bean, grown on soils with different salt content and transplanted in two different times (ordinary and postponed), and to evaluate the possible interactions between salt stress and high temperature stress, due to the later transplant.

Material and Methods

The experiment was made in Portici, at experimental field of Naples Faculty of Agriculture (N 40° 48.870’; E 14° 20.821’; 70m a.s.l.) in 2005. The shelter was a 116 m^2

(14.5 m *x* 8 m) permanent metal structure, open on the sides and with a clear PVC top. The snap bean cultivar “*Bolero*” was transplanted in 0.38 m^{-2} lysimeters (0.7 m diameter and 0.60 m deep), placed on bricks at 0.2 m from the soil surface. Lysimeters were filled with 0.10 m of gravel for drainage and 0.45 m of loamy sandy soil (ISSS classification, Table 1).

Table 1. Soil physical and chemical characteristics.

Coarse sand	%	47.0
Fine sand	%	36.6
Silt	%	11.9
Clay	%	4.5
N (Kjeldahl method)	%	0.091
Assimilable P_2O_5 (Olsen method)	ppm	6.7
Exchangeable K_2O (ammonium acetate method)	ppm	107.0
Organic matter (bichromate method)	%	0.72
Bulk density	kg dm^{-3}	1.32

For this trial a loamy sand soil was chosen for avoiding salt indirect effects on soil physical properties like: swelling, reduction of hydraulic conductivity and related phenomena typical of clayey soils, as reported by Rhoades et al. (1992) e De Pascale and Barbieri (2000).

Two transplant times and five levels of salt stress were tested in factorial combination. Transplant times were: ordinary (first week of June=OT) and postponed (first week of July=PT).

Salt levels were:

1) Well-watered: irrigation with freshwater (ECw 0.7 dS m^{-1}), restoring the water uptake (WW);
2) Low saline stress: 100% of ETc with water at 3.0 dS m^{-1} electrical conductivity (ECw3).
3) Moderate saline stress: 100% of ETc with water at 6.0 dS m^{-1} electrical conductivity (ECw6).
4) Severe saline stress: 100% of ETc with water at 9.0 dS m^{-1} (ECw9).
5) Very severe saline stress: 100% of ETc with water at 12.0 dS m^{-1} (ECw12).

Each of the 10 factorial combinations of treatments was replicated 6 times and distributed in randomised blocks in the shelter, for a total of 60 lysimeters.

In both cycles, eight plants per lysimeter were transplanted at a distance of 0.15 m (21 plants m^{-2}).

Before the transplant, 14.5 g of superphosphate, 8 g of potassium sulphate and 4.5 g of ammonium nitrate were applied in each lysimeter, corresponding to 70 kg ha^{-1} of P_2O_5, 100 kg ha^{-1} of K_2O and 30 kg ha^{-1} of N.

At transplant and in two successive dates, 6 (OT) and 8 (PT) litres of freshwater were applied to each lysimeter in order to help plant establishment.

Starting from 17 days after transplant (DAT) in the OT cycle and at 11 DAT in PT cycle, all lysimeters were irrigated twice a week with an amount of water corresponding to the complete replacement of evapotranspiration. Crop evapotranspiration was estimated by the agrometeorological approach based on Hargreaves formula (to calculate ETo) and a crop coefficient fixed at 1 to have water surplus for leaching the root zone.

For the OT cycle saline waterings were 8 with an average volume of 3.6 litres per lysimeter; in total 55.7, 111.4, 222.8 and 445.6 g of salt per lysimeter were given for treatments ECw3, ECw6, ECw9 and ECw12 respectively. For the PT cycle saline waterings were 7 with an average volume of 4.0 litres per lysimeter; in total 53.8, 107.6, 215.2 and 430.4 g of salt per lysimeter were given for treatments ECw3, ECw6, ECw9 and ECw12 respectively.

Saline water for the stress treatments was obtained by diluting marine salt in freshwater. Each level of EcW was reached by adding marine salt, according to the relation:

Salt% = 0.64 x EC.

The electrical conductivity of the solution (ECw) was checked with a conductimeter.

Still, in both cycles the snap bean succeeded at two lettuce cycles irrigated with five saline water levels, therefore saline treatments has been applied to lysimeters with increasing starting saline soil level, as shown in table 2.

Table 2. Starting and final soil EC and pH (average of two cycles) for each treatment.

Salt level	Starting		Final	
	EC (dS m^{-1})	pH	EC (dS m^{-1})	pH
0.7	0.30	7.43	0.32	7.54
3.0	0.60	7.60	0.71	7.58
6.0	0.77	7.34	1.08	7.45
9.0	1.38	7.29	1.89	7.38
12.0	1.50	7.29	2.85	7.63

Plants were sampled in four phases (after transplanting, flowering-pod setting, pod growing, and harvest), with the aim to measure: green and yellow leaves number, fresh and dry weight, stem length, fresh and dry weight, pod fresh and dry weight (when present). Dry matter values were determined after oven-drying at 60°C until constant weight. Leaf area was measured with a Li- Cor 3000 Leaf area meter.

Pods were harvested in 3 times from July 15 to 23 for the first cycle and from July 28 to August 04 for the second one. They were counted, weighed and classified in marketable (length > 6 cm) and not-marketable ones (length < 6 cm and/or deformed pods).

All the data were analyzed by ANOVA, with the MSTAT software.

Results

Soil salinity

Irrigation with saline water resulted in increased values of soil salinity at harvest (Table 2), especially for the highest saline treatments. In fact, there was not increase for WW and the increase was limited to 0.11 dS m^{-1} for ECw3 treatment. Instead, the average increase was 0.41 dS m^{-1} for ECw6 and ECw9 treatments and 1.35 dS m^{-1} for ECw12 treatment.

pH values showed a light increase at harvest: 0.13 on the average with a maximum of 0.34 in ECw12 treatment.

Temperatures

Air temperature trend was the typical one for the Mediterranean area and the season (Table 3).

Temperatures in the shelter (Figure 1), obviously were always higher than the external ones; in particular, they were 4 °C higher than those external for maximum temperatures and 3 °C for minimum temperatures.

Table 3. Min and max temperatures (°C) during two crop cycles compared to the 30 years mean values.

	Crop cycles		Average1921-1950	
	min	max	min	max
June	17.9	27.3	17.8	27.1
July	20.3	30.2	20.2	30.1
August	19.5	29.0	20.2	29.9

At the ordinary transplant (first week of June) average temperature was almost 24.6 °C, while at postponed transplant (first week of July) it was 28.3 °C.

During the first cycle temperatures showed 5 °C increase from transplant to harvest, while during the second one they were on constant values up to the harvest.

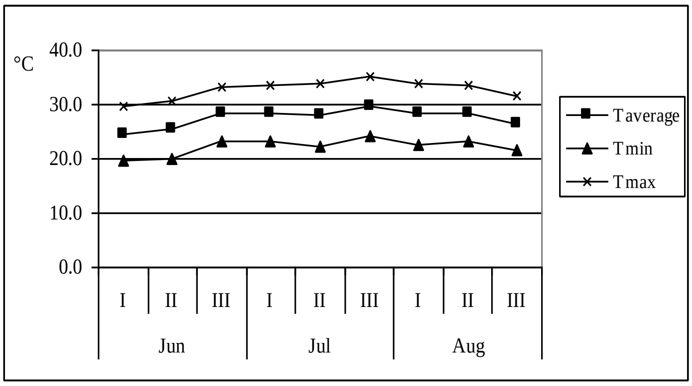

Figure 1. Temperature trend in the shelter during the two cycles.

During the whole period of the experiment, daily excursion of temperatures was 10.7 °C on the average with minimum temperatures ranging from 19.5 to 24.3 °C and maximum from 29.7 to 35.2 °C, thus overcoming the critical temperature for snap bean that causes flowers abscission, sterility, deformity and ripening difficulty of pods.

In this trial, the seedlings PT were exposed for most of cycle at daily temperatures of 35 °C or higher (last week of July).

Average temperatures were used to calculate the Growing Degrees Days (GDD) with the formula:

GDD = $\sum$ [(Tmax-Tmin)-Vegetative zero].

The vegetative zero is the temperature threshold for plant growth (10 °C for snap bean).

Growth

The plants of the four salt treatments showed a different percentage of survival at transplant vs. the WW treatment (Table 4), related to different initial conditions of soil salinity and then to saline waterings.

Table 4. Plant survival percentage from transplant to harvest in the two cycles.

Treatments	Survival percentage vs WW								
	DAT								
	5	10	15	20	25	30	35	40	45
OT									
ECw3	84.0	82.7	81.3	81.3	81.3	77.8	75.7	70.3	68.9
ECw6	47.0	45.3	40.0	39.3	37.3	21.5	13.5	10.1	8.1
ECw9	53.0	52.0	44.0	42.7	30.7	8.0	5.4	5.4	0.0
ECw12	29.0	26.7	14.7	8.7	2.7	1.4	0.0	0.0	0.0
PT									
ECw3	100.0	99.6	99.2	99.1	94.9	82.8	78.3		
ECw6	92.5	91.7	91.5	90.6	69.7	44.8	39.1		
ECw9	85.8	74.0	54.2	44.4	23.5	12.9	0.0		
ECw12	32.5	18.4	7.6	5.1	5.1	0.0	0.0		

Mortality of ECw12 plants was especially due to soil salinity (Table 2) because almost all plants (85.3% in OT cycle at 15th day and 81.6% in PT cycle at 10th day) died before the starting of saline irrigations. For this reason these plants were excluded from samplings. Plant survival percentage of the other saline treatments (ECw3, ECw6 and ECw9) was greater but, however, decreasing as increasing salt concentration in soil and water irrigation; in particular the ECw9 plants did not reach ripening.

The two cycles had a different length; for ripening of OT cycle 791.0 GDDs were necessary vs. 659.1 of PT cycle, but the first pods were formed almost after the same DAT). In fact, for the plants of OT cycles the first pods were sampled at 28 DAT (465.4 GDD) and for the PT plants the first pods were sampled at 27 DAT (497.8 GDD). But during pod ripening OT plants accumulated other 325.6 GDD vs. 161.3 GDD of PT plants. In fact the more high temperatures of PT cycle determined flowers and pods abscission (less number of pods per square meter), pods deformity and lower average weight.

The salt stress reduced plants height, while heat stress increased it; in fact the plants of PT cycle (Figure 2b) were always slightly taller than corresponding OT plants (Figure 2a); besides, in both cases, the least stressed treatment (ECw3) did not show statistic differences from the control irrigated with fresh water.

Assimilated partitioning on total dry weight (Figure 3a and 3b) had a different trend in the two cycles. Only stem percentage was approximately the same during the two cycles (almost 40%) for every treatment without differences between them.

Salt stress determined a drying of plants, but the high temperature stress increased this drying process; in fact, already at 15 DAT in the PT plants there were the first yellow leaves also for the ECw6 and not only for the ECw9, as shown in the OT cycle.

Green leaves incidence of PT plants drastically decreased during the cycle until to be practically zero at harvest, except for the control (15%); at PT cycle harvest, also the saline treatments showed a considerable presence of green leaves; in fact the plants drying process was more early but less drastic (greater equilibrium between green and yellow leaves).

Finally, salt stress reduced pod production, but heat stress was more strong, because in the PT cycle pod production had a smaller incidence on total plant dry matter, also for the control.

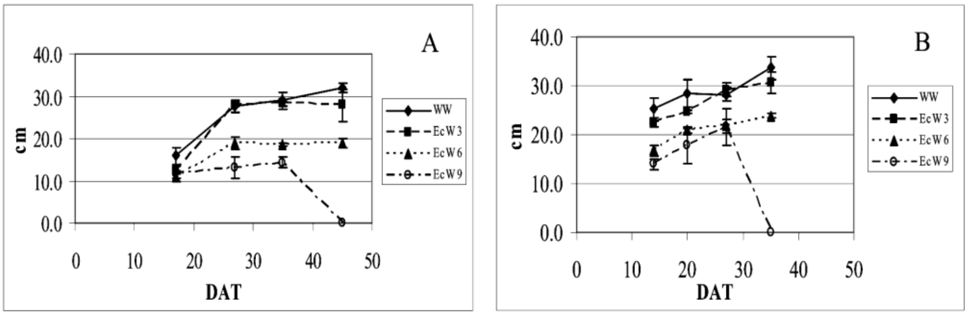

Figure 2. Height of snap bean plants irrigated with water of different salt content: A) for ordinary transplant (OT), B) for postponed transplant (PT). Values are means of three samples (when possible). Vertical bars represent the standard deviation.

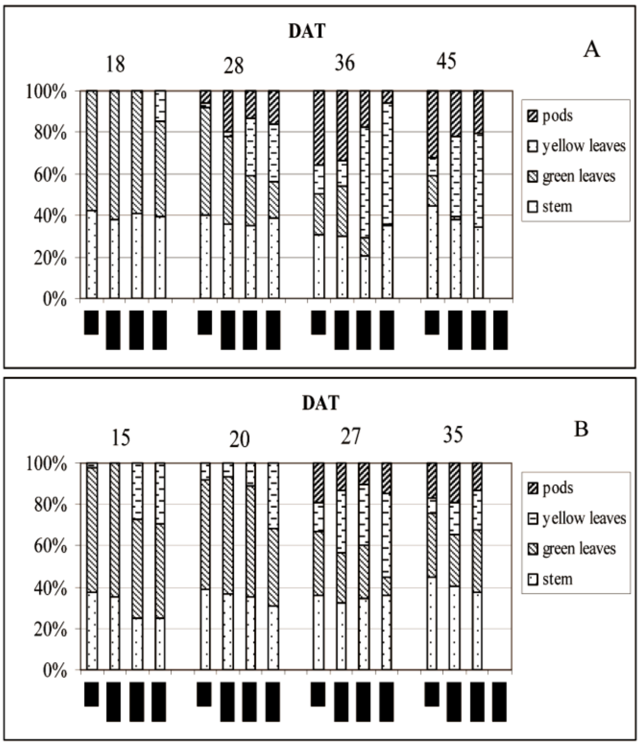

Figure 3. Assimilated percentage partitioning on the total plant dry matter. A) in the OT cycles; B) in the PT cycles.

The different dry biomass accumulation of OT and PT plants is showed in figures 4a and 4b. Salt stress always reduced plant growth. The aboveground biomass of ECw6 and ECw9 of OT plants were not different from those of PT, thus indicating that the salt stress was more strong than heat stress. Instead, control and ECw3 treatment of OT cycle were greater than the corresponding treatments of PT cycle, respectively more 94.1 and 49.8%, thus suggesting that temperature stress could be more strong.

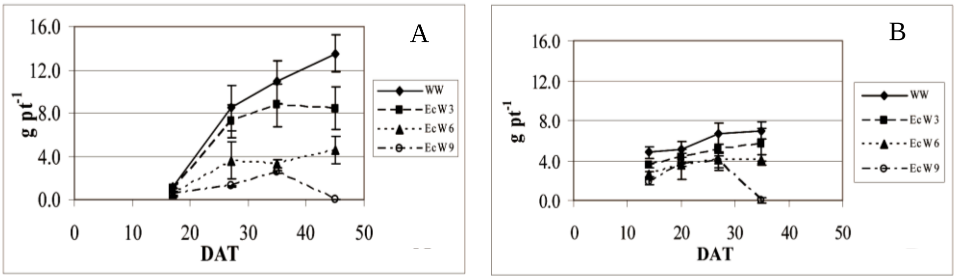

Figure 4. Total aboveground biomass of snap bean irrigated with water of different salt content A) for ordinary transplant (OT), B) for postponed transplant (PT) vs. time (days after transplanting). Values are means of three samples (when possible). Vertical bars represent the standard deviation.

The growth trend of the plants of two cycles was different, because the higher temperatures of PT cycle have initially stimulated plant growth (at 15 days from transplant the average aboveground dry biomass was 4 g plant^{-1} for PT cycle and only 2 g plant^{-1} for OT), but then (from half July), when temperatures further increased (35 °C), plant growth was markedly more slow in all treatments, so that salt effects was less evident. Instead, during OT cycle the temperatures gradually increased, allowing also a more regular growth of plants. Therefore the plants did not suffer heat stress and the growth differences due the salt stress were more evident.

The salt effect (Figure 5a and 5b), according with other authors (Bray and Reid, 2002; Brugnoli and Lauteri, 1991), reduced leaf area of plants.

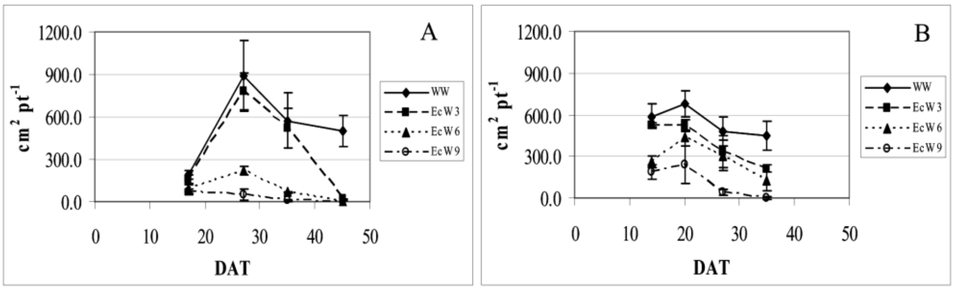

Figure 5. Leaf area of snap bean plants irrigated with water of different salt content A) for ordinary transplant (OT), B) for postponed transplant (PT) vs. time (days after transplanting). Values are means of three samples (when possible). Vertical bars represent the standard deviation.

In OT cycle (Figure 5a), leaf area increased until the middle of growth cycle for WW and ECw3 and it decreased in the following samplings, resulting at the harvest next to zero, except for WW treatment.

Although during the phases of maximum growth control and ECw3 showed leaf area values lower than those of OT cycle, at harvest all plants of PT cycle (Figure 5b) had higher leaf area values.

In fact, in OT cycle at harvest the decrease of leaf area percentage of all saline treatments vs. WW was next to 100%, while in PT cycle only ECw9 plants showed 100% decrease of leaf area percentage (Table 5).

Table 5. Leaf area decrease (%) vs. WW of saline treatments of two cycles.

Treatments		Samplings			
Transplant	Salt	I	II	III	IV
Ordinary	ECw3	15.3	12.9	9.0	96.7
	ECw6	50.4	75.1	87.8	100.0
	ECw9	61.8	94.6	99.0	100.0
Postponed	ECw3	10.3	23.3	29.9	52.4
	ECw6	55.4	36.0	36.2	73.0
	ECw9	67.7	64.5	91.2	100.0

About the number of green leaves, the interaction between transplant time and saline irrigation water was significant. Green leaves number decreased as increased salt concentration and temperature, in fact, above all OT plants irrigated with fresh water had an average number of green leaves of 52.0 vs. 27.8 of well watered PT plants, while the saline treatments showed similar values in both cycles.

Table 6. Number of green leaves per plant: Interaction transplant time x saline irrigation water Different letters show significant differences (P=0.05).

Treatments	green leaves n° pt^{-1}	
	OT	PT
WW	52.0 a	27.8 b
ECw3	28.5 b	22.0 bc
ECw6	15.0 cd	17.7 cd
ECw9	11.0 d	10.2 d
LSD	10.4	

The lower number of leaves for PT plants was compensated by the higher leaf area (Table 7), in comparison with OT cycle (16.2 vs. 6.5 respectively); however, saline stress determined a significant decrease of leaf average area; in fact only ECw3 treatment was not different from control irrigated with fresh water.

Yield

Snap bean yield was strongly influenced by the saline stress, especially in the postponed transplant cycle; in fact, in both cycles, ECw12 and ECw9 treatments did not produce marketable pods.

Particularly, the statistic analysis showed an interaction between transplant time and water salinity for marketable pod number per square meter, total and marketable yield (Table 8).

These three parameters had similar trends. Particularly, OT control showed always higher values than all the other treatments and double also of the PT control; because temperatures higher than 30 °C caused flowers abscission and further 32-37 °C determined fruits deformity with yield decrease.

The degree of salt stress was more strong than high temperature stress in all the saline treatments; also if, combined with high temperature, caused further decreased of yield, although without significant differences among OT and PT plants. The effect of high temperature of postponed transplant, instead, was more evident for control plants, which were only affect by this type of stress.

Table 7. Effect of transplant time and saline irrigation water on average area of green leaves. Different letters show significant differences (P=0.05).

Treatments	green leaves	
	$cm^2\ fg^{-1}$	
WW	15.1	a
ECw3	12.8	ab
ECw6	10.5	b
ECw9	6.8	b
LSD	3.8	
OT	6.5	b
PT	16.2	a
LSD	5.1	

Table 8. Marketable (g m^{-2} and n° pods m^{-2}) and total yield: interaction transplant time x saline treatments Different letters show significant differences (P=0.05).

Treatments		Pods		Yield			
Transplant	Salt	Marketable		Marketable		Total	
		n° m^{-2}		g m^{-2}		g m^{-2}	
Ordinary	WW	193.4	a	446.8	a	490.6	a
	ECw3	70.0	bc	161.0	bc	199.3	bc
	ECw6	9.9	d	22.5	d	43.0	d
Postponed	WW	100.4	b	206.7	b	253.5	b
	ECw3	52.0	c	100.7	c	122.8	c
	ECw6	5.1	d	9.2	d	23.9	d
	LSD	38.4		75.5		77.8	

About plant and pod number per square meter and average weight of marketable pods (Table 9), the effects of main factors (salt and transplant time) were significant.

The differences due to salt stress were always significant except for the average weight of marketable pods.

The high temperature stress determined a decrease of total pods number per square meter and the average weight of marketable pods; contrarily, plant density at harvest was greater in postponed transplant cycle, however without compensating yield losses.

Table 9. Effect of transplant time and saline irrigation water on plants and total pods per m^2 and marketable pods average weight. Different letters show significant differences (P=0.05).

Treatments	Plants		Pods			
			Total		Marketable	
	n° m^{-2}		n° m^{-2}		g $pods^{-1}$	
WW	24.7	a	215.9	a	2.15	ns
ECw3	18.9	b	122.0	b	1.94	ns
ECw6	14.8	c	43.4	c	1.76	ns
LSD	2.8		43.3		0.47	
Ordinary	18.1	b	149.1	a	2.12	a
Postponed	20.9	a	105.1	b	1.78	b
LSD	1.9		30.0		0.32	

Discussion

As for many other crops, also for snap bean, the first salt effect is a growth reduction, according to many other authors (Bayuelo-Jemenez et al., 2003; Lovelli et al., 2000; Brugnoli and Lauteri, 1991).

Munns et al. (1995) proposed a model of biphasic response of the plants to salinity. The plants growth is initially reduced, because the roots absorb less water, due to low water potential of soil. In this phase plant suffers osmotic stress in function only of salt concentration and osmotic pressure, but not of the salt type. Then, the further inhibition of plant growth is due to toxic stress initially shown in the old leaves, that die because increasing salt concentration. When the abscission of old leaves is greater than neosynthesis, the availability of assimilated decreases such as plant growth.

The reduced growth due to salt stress showed a decrease of dry matter accumulation, height, leaf area, number of green leaves (more evident in OT cycle) and their average area. Besides, the salt stress determined an early senescence of plants, at least for the most stressed treatments.

High temperature stress in PT plants increased plant height but, because the percentage incidence of the stems on the total plant dry matter was not different in the two cycles (approximately 40%), this means that plants lengthened the stems, thinning them.

Besides, heat stress caused a decrease of total aboveground biomass, because high temperatures have a direct effect on the plant growth, confirming the results of Omae et al. (2006) who observed on different genotypes of *Phaseolus vulgaris* that high temperatures (30/26 °C respectively diurnal and night time) involve a weight decrease of plants. Also in maize, pearl millet and sugarcane, high temperatures caused significant declines in shoot dry mass, relative growth rate and net assimilation rate (Ashraf and Hafeez, 2004; Wahid, 2007).

High temperature stress reduced also the number of green leaves, but with the significant differences only for the control. Instead, the average area of green leaves was higher, so at harvest the more high leaf area of PT plants was due to higher average area of green leaves but also to the higher number of leaves per plant.

In fact, in PT cycle, control, ECw3 and ECw6 treatments had green leaves at harvest, although in quantity halved against to the initial phases of the cycle (30% vs. 60%), contrarily at the harvest of the OT cycle, only control had a moderate quantity of green leaves (around 15%).

In OT cycle the drying process began later, but at the end of cycle it interested almost all plants, while in PT cycle the first yellow leaves were noticed after 15 days in the two more stressed treatments, but until to harvest there was a greater equilibrium with green leaves, as shown by the greater final values of leaf area.

In both cycles the leaves senescence was greater in the more stressed treatments, according with Lovelli et al. (2000). In effect, Munns and Termaat (1986) and Munns et al. (1995) suggest that salt concentrations at given time of exposure to salinity are always the highest in the oldest leaves that show an early death. The higher salt concentrations in the older leaves of non-halophytes may result entirely from a product of time by transpiration rate (Greenway and Munns, 1980) or at least partly from an exclusion of specific ions from the xylem vessels supplying the younger leaves (Yeo and Flowers, 1982), but Munns and Termaat (1986) think that this phenomenon could be adaptive.

Salt and heat stress determined also the reduction of yield, as showed also by Bustan et al. (2004) in potato crops. Particularly, total and marketable yield decreased as increased salt concentration and temperature but, while the salt effect was prevalent in all saline treatments, the heat stress had a greater effect on the control, which had less than 50% of OT WW yield. However, all plants of PT cycle didn’t reach a good level of production, as found also by Rainey and Griffiths (2005), because of the smaller size of plants and the lower number of marketable pods due to the effect of a period of heat stress on floral buds and opened flowers abortion (Wahid et al., 2007) and abscission and deformity of fruits. In fact the not marketable pods percentage on the total yield ranged for the OT cycle between 8.9% (WW) and 47.7% (ECw6) and for PT cycle between the 18.5% (WW) and 61.5% (ECw6). Besides, Shannon and Grieve (1999) report that high temperatures and low humidity may decrease crop salt tolerance, thus significant reduction of yield will be realized at lower salinities, and yields will decrease more rapidly with increasing salinity under hot and dry conditions.

The PT yield reduction was due also to lower average weight of marketable pods, not compensated by higher plant density at harvest.

In reality, in PT cycle the higher temperatures (25 °C on the average) shortened the cycle duration: 35 days vs. 45 of OT cycle and also plant growth and yield were smaller.

The cycle shortening interested above all the reproductive phases (pods formation and filling), that lasted 15 days in OT cycle and 9 in PT.

Particularly, the shorter production period involved a smaller average weight of the marketable pods, probably, because the lower growth of plants determined a lower photosynthate availability for the filling pods phase, in fact the pods lengthened but without a "regular" filling of seeds.

The irregular photosynthetic activity is confirmed also by Zhang et al. (2005) who revealed that specific effects of high temperatures on photosynthetic membranes result in the loss of grana stacking or its swelling. In response to heat stress, chloroplasts in the mesophyll cells of grape plants became round in shape, the stroma lamellae became swollen, and the contents of vacuoles formed clumps, whilst the cristae were disrupted and mitochondria became empty. Such changes result in the formation of antenna-depleted photosystem-II (PSII) and hence reduced photosynthetic and respiratory activities.

Conclusion

The salt effect, in both cycles, caused a growth reduction of plants; particularly the plant treated with saline water irrigation were taller, the total aboveground biomass decreased notably, such as also the leaf area. Besides, salt stress reduced total yield of snap bean both because the reduced plant growth and because the percentage of plants survival decreased with saline stress. Particularly, the saline stress reduced the number of pods (total and marketable) per square meter, but not their average weight.

Also transplant time influenced snap bean growth and yield. In fact, the total aboveground biomass was lower in PT cycle, such as leaf area, but only for WW and ECw3 treatments.

High temperatures of PT cycle shortened cycle duration; particularly heat stress reduced pods formation and filling phases, in fact the number of total pods per square meter and the average weight of marketable pods were higher in OT cycle.

Therefore, it seems that it is not favourable to postpone the transplant time in snap bean irrigated with saline water irrigation, because the yield loss are higher, at least for the cultivar investigated and in the our experimental conditions.

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