Effects of Seedling Age, and Different Levels of N, K and K/N on Quality and Yield of Tomato Grown in Perlite Bag Culture

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The object of the study was to investigate the effects of seedling age, and different levels of N, K and K/N on growth and yield of tomato grown in perlite bag culture. Seeds of Big Boy F1 sown in perlite and subsequently seedlings were planted in ten-liter PE bag filled with coarse perlite. Four fertigation regimes were applied to the plants concerning four N (103, 110, 113 and 120 mg/l), four K (186, 195, 258 and 275 mg/l) and two K/N (1,6 and 2,5) levels. Thrace element levels were the same for all the gertigation regimes. Seedling were planted at three different growth stages; *1)*appearence of first inflorescence, *2)*50% flower opening on first cluster and *3)*fruit set on first cluster. Altough effects of seedling age on total, marketable and early yield, and cracking and Blossom-end rot occurrence were not statistically significant, total, marketable and early yield were higher when the seedling were planted at the time of fruit set on first cluster. The highest total, early and marketable yields were obtained from the transplants planted at fruit set on first truss with FR1 (plants were fertigated with the high K/N starter solution: K/N= 2,5; 110 mg l^{-1} N and 275 mg l^{-1} K until the fruits on the first truss reached 2cm in diameter, then with the low K/N mainfed solution; K/N= 1,6; 120 mg l^{-1} N and 195 mg l^{-1} K for the rest of the vegetation).

Keywords: Seedling age, K/N ratio, soilless culture, tomato, nitrogen, potassium

Introduction

A common problem associated with hydroponically grown plants is the excessively strong growth can occour after planting the seedlings. Strong plants are difficult to train and suffer from poor flower set.

The seedlings should be planted when the first truss is well in flower, or a little earlier for late crops, to encourage good early fruit development. It may be possible to delay planting a little longer providing the seedling in perlite pots are given adequate amount of nutrient in bright weather. But in our country, seedlings are grown in modules filled with peat and are planted at 3-4 true leaf stage. This makes the control of early season vigour difficult.

The usual remedies to control the vegetative vigour are; to restrict water availability by increasing the conductivity of the nutrient solution until the fruit load takes over, then reduce the conductivity gradually (Day, 1991) or to use nitrogen restriction or low salt nutrient regime by using solution relatively low in nitrogen but high in potassium. In perlite growing systems, the high substrate capillary makes it very difficult to restrict water and once salts built up they are difficult to displace by flushing out with plain water or low nutrient solution.

Therefore stage of planting, different levels of N, K and N/K ratios are tried for curbing excessive early season vigour, for improving fruit yield and quality and for encouraging good early fruit development of tomato grown in perlite bag culture in this experiment.

Materials and Methods

Experiment was conducted in spring-early summer growing period in polythene house. Seeds of Big Boy F1 were sown in black PE bag filled with coarse perlite.

Four fertigation regimes concerning various N and K levels and K/N ratios applied to the plants were:
Fertigation regime 1 (FR1): plants were fertigated with the high K/N ratio starter nutrient solution (NS1: 110 mg l^{-1} N and 275 mg l^{-1} K; K/N ratio= 2,5; pH=5,8; EC=2000 µmhos cm^{-1}; 4,9% of total N is NH_4-N) until the fruits on the first cluster reached 2cm in diameter, then with the low K/N ratio mainfed nutrient solution (NS2: 120 mg l^{-1} N and 195 mg l^{-1} K, K/N ratio= 1,6; pH=6,2; EC=2200 µmhos cm^{-1}; 4,5% of total N is NH_4-N) for the rest of the vegetation period.
Fertigation regime 2 (FR2): plants were fertigated with the low K/N ratio nutrient solution (NS2: 120 mg l^{-1} N and 195 mg l^{-1} K, K/N ratio= 1,6; pH=6,2; EC=2200 µmhos cm^{-1}; 4,5% of total N is NH_4-N) for the entire vegetation period.
Fertigation regime 3 (FR3): plants were fertigated with the high K/N ratio nutrient solution (NS3: 103

mg l^{-1} N and 258 mg l^{-1} K; K/N ratio= 2,5; pH=5,5; EC=2000 µmhos cm^{-1}; 5,3% of total N is NH_4-N) until the fruits on the first cluster reached 2cm in diameter, then with the low K/N ratio nutrient solution (NS4: 113 mg l^{-1} and 186 mg l^{-1} K, K/N ratio= 1,6; pH=6,2; EC=2200 µmhos cm^{-1}; 4,8% of total N is NH_4-N) for the rest of the vegetation period.
Fertigation regime 4 (FR4): plants were fertigated with the low K/N ratio nutrient solution (NS4: 113 mg l^{-1} N and 186 mg l^{-1} K, K/N ratio= 1,6; pH=6,2; EC=2200 µmhos cm^{-1}; 4,8% of total N is NH_4-N) for the entire vegetation period.

Nutrition solution (NS) contents including ions from water and diluted acid solution of HNO_3%3+H_3PO_4%7 (used for balancing the pH of nutrient solution; injection rate: 1/100) were, (mg l^{-1});
NS1:110N; 51P; 275K; 125Ca; 31Mg; 1,5Fe; 111S; 0,7Mn; 0,3B; 0,2Zn; 0,2Cu; 0,05Mo (K/N=2,5; K/Ca=2,2; Ca/Mg=4,0; EC=2000µmhos cm^{-1}; pH=5,8 and 4,9% of total N is NH_4-N)
NS2: 120N; 51P; 195K; 125Ca; 39Mg; 1,5Fe; 79S; 0,7Mn; 0,3B; 0,2Zn; 0,2Cu; 0,05Mo (K/N=1,6; K/Ca=1,5; Ca/Mg=3,2; EC=2200µmhos cm^{-1}; pH=6,2 and 4,5% of total N is NH_4-N)
NS3: 103N; 51P; 258K; 125Ca; 25Mg; 1,5Fe; 104S; 0,7Mn; 0,3B; 0,2Zn; 0,2Cu; 0,05Mo (K/N=2,5; K/Ca=2,0; Ca/Mg=5,0; EC=2000µmhos cm^{-1}; pH=5,6 and 5,3% of total N is NH_4-N)
NS4: 113N; 51P; 186K; 125Ca; 34Mg; 1,5Fe; 75S; 0,7Mn; 0,3B; 0,2Zn; 0,2Cu; 0,05Mo (K/N=1,6; K/Ca=1,5; Ca/Mg=3,7; EC=2200µmhos cm^{-1}; pH=6,2 and 4,8% of total N is NH_4-N)

Chemical contents of water were; pH=8,2; EC=400 µmhos cm^{-1}; HCO_3=189 mg l^{-1}; Mg^{++}=7 mg l^{-1}¸ Ca^{++}=36 mg l^{-1}

Seedlings were planted at three different growth stages; *1)*appearence of first inflorescence; 7 week-old (AI), *2)*50% flower opening on first truss; 8,5 week-old (FO) and *3)*fruit set on first truss; 10,5 week-old (FS).

All side shoots of plants, in all seedling ages, removed periodically when shoots were 3-5cm long. Plants were topped to leave 4 trusses on a plant and fruits were thinned to leave 5 fruits.
7gN m^{-2} (calcareous ammonium nitrate, 26% N) and 12gK m^{-2} (K_2SO_4, 42% K) was applied in the soil parcel every 15 days as dry fertilizers.

Results and Discussion

Seedling age and fertigation regimes main effect did not significanly influenced total, marketable and early yield. The effect of Seedling age on yield differed depending on fertigation regimes. Total and early yields of FS Seedling were higher from fertigation regime 1 (FR1) and fertigation regime 2 (FR2) than those from fertigation regime 3 (FR3) and fertigation regime 4 (FR4). It should be noted that FR1 was the one of the nutrient regimes which K/N ratio was reduced from 2,5 to 1,6 when the fruits on the first truss reached 2cm in diameter and FR2 was the the one of the nutrient regimes which K/N ratio was 1,6 for the entire vegetation period and only differences in same K/N ratio regimes were N and K content of the solution (Table 1).

Table 1. Effects of seedling age and fertigation regimes on total, marketable, and early yield of tomato (g $plant^{-1}$)

	Total yield				Early yield				Marketable yield			
	AI	*FO*	*FS*	mean	*AI*	*FO*	*FS*	mean	*AI*	*FO*	*FS*	mean
FR1	2478^{ab}	2306^{ab}	3154^{a}	2646	1283	1115	1540	1313	1942	2140	2982	2355
FR2	2563^{ab}	2573^{ab}	3007^{a}	2714	1270	1258	1363	1297	2234	2276	2911	2474
FR3	2448^{ab}	2371^{ab}	2589^{ab}	2469	1168	1175	1223	1189	2099	2168	2371	2213
FR4	2511^{ab}	2666^{ab}	2450^{ab}	2543	1210	1208	1118	1179	2268	2326	2170	2255
soil	-	-	-	1834^{b}	-	-	-	1065	-	-	-	1770
mean	2500	2479	2800	-	1233	1189	1311	-	2136	2228	2609	-

AI:appearence of first inflorescence; *FO*: 50% flower opening on first truss; *FS*: fruit set on first truss; *FR1*: K/N ratio of nutrient solution decreased from 2,5 (110 mg/l N and 275 mg/l K) to 1,6 (120 mg/l N and 195 mg/l K); *FR2*: K/N ratio of nutrient solution was 1,6 (120 mg/l N and 195 mg/l K) for the entire vegetation period; *FR3*: K/N ratio of nutrient solution decreased from 2,5 (103 mg/l N and 258 mg/l K) to 1,6 (113 mg/l N and 186 mg/l K); *FR4*: K/N ratio of nutrient solution was 1,6 (113 mg/l N and 186 mg/l K) for the entire vegetation period. %5 LSD for combinations= 1211.

Similar total and marketable yields with FR1 and FR2, as in with FR3 and FR4, indicate that, in addition to K/N ratio, N and K content of the solutions seems to have an influence on the yield.

The effect of K/N ratio of solution on yield was depended on N and K content of the solutions. In FR1 and FR3, K/N ratio of the nutrient solutions were 2,5 until the fruits on the first cluster reached 2cm in diameter, then decreased to 1,6. On the other hand, in FR2 and FR4, K/N ratio of solution was 1,6 for the entire vegetation period. Although, both in FR1 and FR3, K/N ratios were the same, N and K concentrations of nutrient solutions were different. When the K/N ratio was dropped to 1,6 in FR1, N content of solution increased from 110 mg/l to 120 mg/l and K content decreased from 275 mg/l to 195 mg/l, and in FR3, N content of solution increased from 103 mg/l to 113 mg/l and K content decreased from 258 mg/l to 186 mg/l. In the fertigation regimes, in which K/N ratio was 1,6 throughout the vegetation period; N and K content of the solutions were 110 mg/l and 195 mg/l, respectively, in FR2 and were 113 mg/l and 186 mg/l, respectively, in FR4.

Evaluating the effect of fertigation regime and seedling age on yield revealed more information. Highest yields were observed when seedling were transplanted at fruit set on first cluster with FR1 and FR2 regimes (Figure 1 and Figure 2).

When seedlings were transplanted at appearence of first inflorescence and 50% flower opening on first truss, although statistically not significant, total and marketable yields were lower with the increasing N concentration of nutrient solution when fruits on the first truss reached 2cm in diameter, related to higher N concentration throughout the vegetation period. On the other hand when seedlings transplanted at the fruit set on first cluster yields were similar whether N content increased or remained the same throughout the vegetation period.

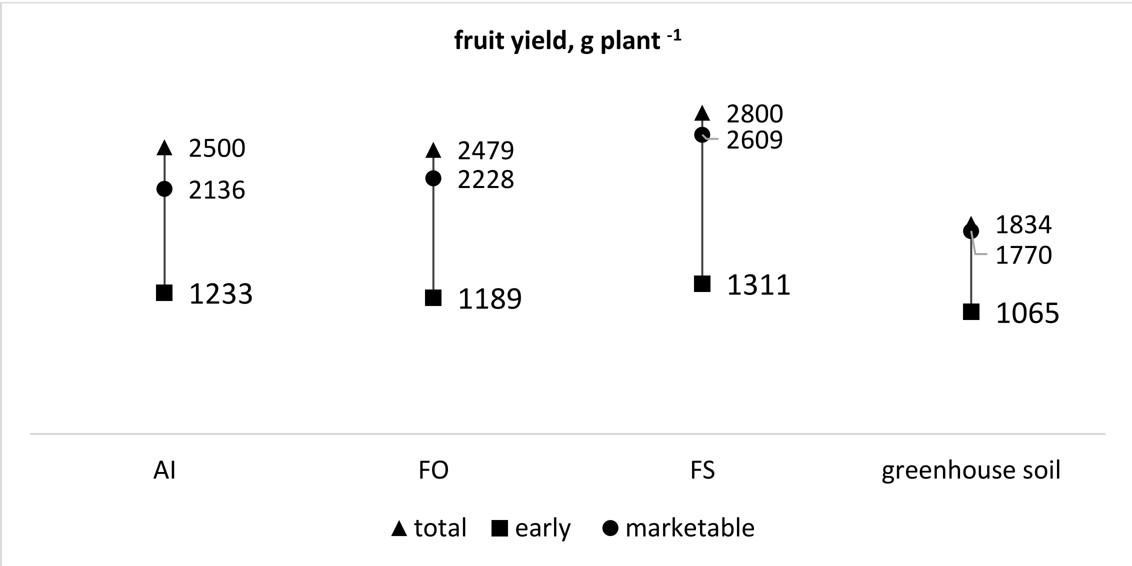

Figure 1. Main effect of seedling age on yield.

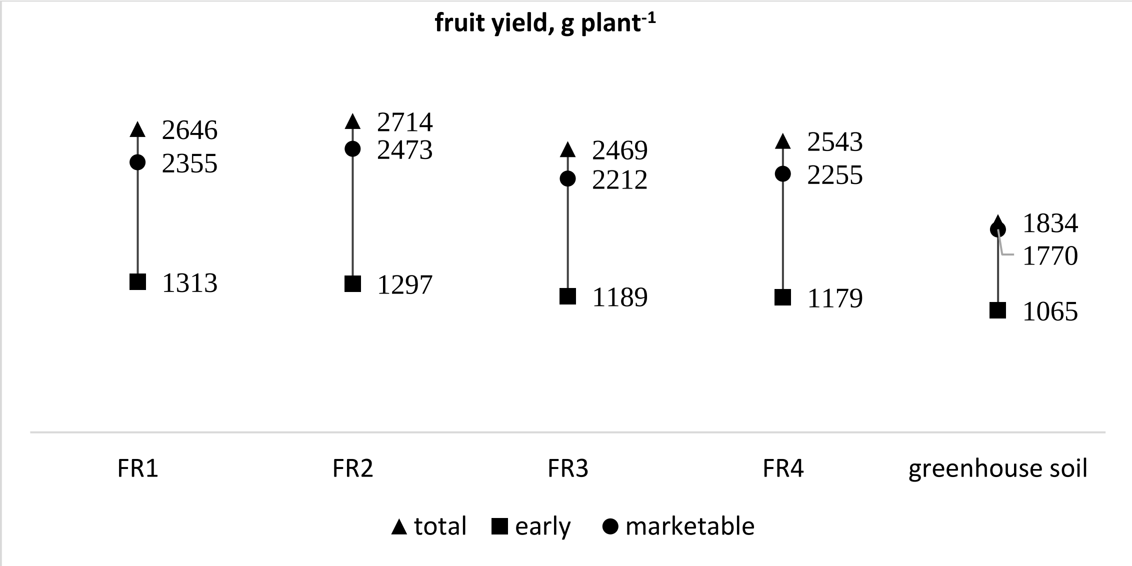

Figure 2. Effect of fertigation regime on yield.

It seems from the results that; restricting nitrogen approach in order to control vegetative vigour and promote early yield also needed to be evaluate together with the N and K contents of solution, as well as with seedling age. Because relative increases in N content (9,0% in FR1 and 9,7% in FR3) and reductions in K content (28% in FR1 and 29% in FR3) were similar in treatments from which similar early yields were observed. As oppose with the suggestion by Vavrina (1991) growth resriction in container with the older seedlings seems to be positively affected early yield. But higher early yields with the older seedlings may be result of fertigation regimes. Transplanting the seedlings at the time of fruit set on first truss and lowering K/N ratio as long as N and K concentrations of the nutrient solution kept relatively higher, promoted early yield.

Due to the scarce of cheap energy sources, one of the most important advantages of the greenhouse growing for the region is early harvest. In this study early yield refers to the fruits harvested until the beginning of the harvest in open field. Seedlings of all ages in this study were spaced more widely and youngest seedling age was considerably older than commerciall ones. Although 7-week old seedlings may seem impractical on a commercial scale as suggested by Vavrina and Orzolek (1993), it may be necessary to use relatively older seedlings to control excessivelly strong growth after transplanting and to encourage good early fruit development in hydroponic. Therefore it may serve as a usefull information to know that early fruit development can be achieved with relatively older seedlings by adjusting of nutrient regimes according to spesific growing period.

Fertigation regimes and seedling age affected individual fruit weight. The highest individual fruit weights were observed with FR1 in all seedling age (Figure 3).

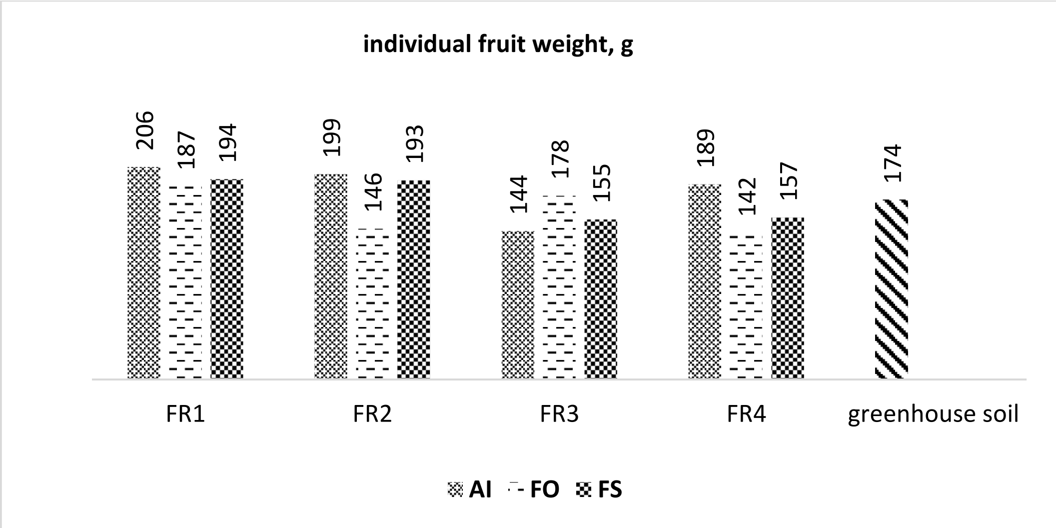

Figure 3. Effects of seedling age and fertigation regime combinations on individual fruit weight

Though similar marketable fruit numbers obtained from seedlings transplanted at fruit set on first truss with FR1, FR2 and FR3 (Figure 4), marketable yield was 25% higher in FR1 and FR2 than it was in FR1.

It seems that, higher marketable yields in FR1 and FR2 were result of higher individual fruit weight. Despite the fact that, seedlings transplanted at at fruit set on first truss with FR3 were manifested in more first class fruit, fruit sizes in this group were either large or small (data not presented). And despite the similar marketable fruit weight, marketable fruit number, individual fruit weight and relative percentage of BER incidence, seedlings transplanted at fruit set on first truss with FR1 produced more first class fruit ((Figure 4).

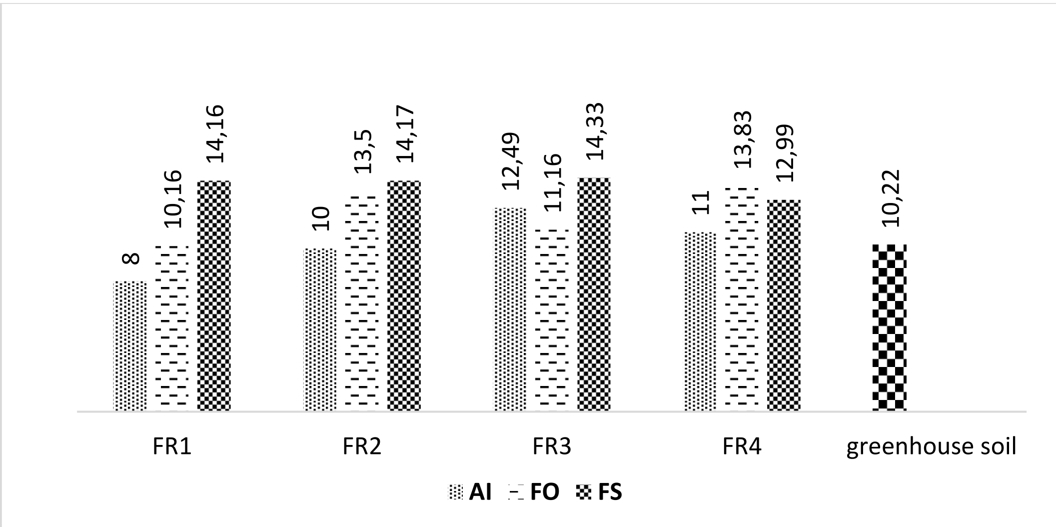

Figure 5. Effects of seedling age and fertigation regime combinations on marketable fruit number

The impact of fertigation regimes on blossom-end rot (BER) incidence varied in accordance with seedling age. It was varied from 5%, to 22% in FR1, from 3%, to 13% in FR2, from 8%, to 14% in FR3 and from 10%, to 11% in FR4 (Table 2).

Table 2. Relative percentage of first class fruit weight, and fruit cracking and blossom-end rot incidence to total fruit weight (%)

	Blossom-end rot				Fruit cracking				First class fruit			
	AI	*FO*	*FS*	mean	*AI*	*FO*	*FS*	mean	*AI*	*FO*	*FS*	mean
FR1	22	7	5	11	53	76	53	60	24,9	17,3	41,6	29
FR2	13	12	3	9	79	52	67	66	8,2	36,8	29,7	25
FR3	14	9	8	10	52	78	44	58	33,6	13,0	48,0	32
FR4	10	13	11	11	78	62	69	69	11,6	25,6	20,2	19
soil	-	-	-	3	-	-	-	12	-	-	-	84
mean	15	10	7	-	66	66	58	-	19	24	35	-

AI:appearence of first inflorescence; *FO*: 50% flower opening on first truss; *FS*: fruit set on first truss; *FR1*: K/N ratio of nutrient solution decreased from 2,5 (110 mg/l N and 275 mg/l K) to 1,6 (120 mg/l N and 195 mg/l K); *FR2*: K/N ratio of nutrient solution was 1,6 (120 mg/l N and 195 mg/l K) for the entire vegetation period; *FR3*: K/N ratio of nutrient solution decreased from 2,5 (103 mg/l N and 258 mg/l K) to 1,6 (113 mg/l N and 186 mg/l K); *FR4*: K/N ratio of nutrient solution was 1,6 (113 mg/l N and 186 mg/l K) for the entire vegetation period.

Blossom-end rot occurrence was lowest when the seedling were planted at the time of fruit set on first truss (Figure 5). As in BER incidence, the effect of fertigation regimes on fruit cracking varied with regard to seedling age. Fruit cracking ratios were between 53%-76% in FR1, between 52%-79% in FR2, between 44%-78% in FR3 and varied from 62%, to 78% in FR4. Reducing K/N ratio from 2,5 to 1,6 when fruits on the first truss reached 2cm in diameter had an improving effect on fruit cracking when seedling transplanted either Aİ or FS (Table 2).

First class fruit ratio was lower with treatments that of fruit cracking ratios were higher. The highest first class fruit ratio was observed with transplanting at fruit set stage in reducing K/N ratio fertigation regimes.

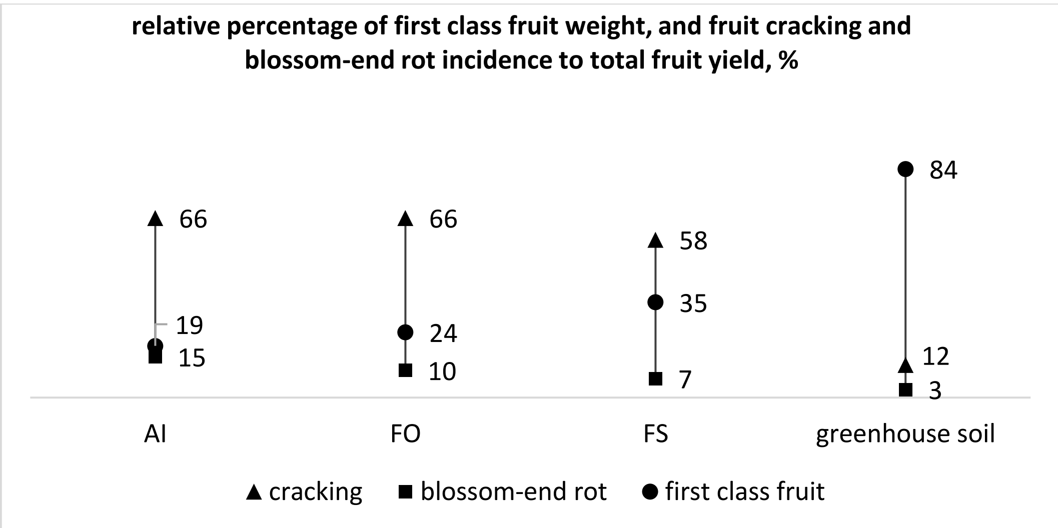

Figure 5. Main effect of seedling age on blossom-end rot incidence, fruit cracking and first class fruit ratio

Conclusions

Regardless of seedling age, it can be speculated that, according to main effects whether K/N ratio was decreased from 2,5 to 1,6 or remained 1,6 throughout the vegetation period, the effect of K/N ratio on yield relates to N and K content of the solution. And higher yields observed when N and K content of solution were higher, since the N and K content of the solution in FR1 were higher than those of FR3 and similarly they were higher in FR2 than those of FR4.

With regards to seedling age, it may be suggested that younger transplants produce higher marketable fruits when K/N ratio of solution was 1,6 throughout the vegetation period while older transplants produce higher marketable yields when K/N ratio of solution reduced from 2,5 to 1,6 when the fruits on the first cluster reached 2cm in diameter.

Transplanting the seedlings at the time of fruit set on first cluster and lowering K/N ratio as long as N and K concentrations of the nutrient solution kept relatively higher, promoted early yield. As the highest total, early and marketable yields were obtained from the transplants planted at fruit set on first truss with FR1 (plants were fertigated with the high K/N starter solution: K/N= 2,5; 110 mg l^{-1} N and 275 mg l^{-1} K until the fruits on the first truss reached 2cm in diameter, then with the low K/N mainfed solution; K/N= 1,6; 120 mg l^{-1} N and 195 mg l^{-1} K for the rest of the vegetation period), this combination can be recommended for the growers. Hydroponic growers in our country also can benefit using transplants which have fruit set on the first truss instead of seedling at 3-4 true leaf stages to achieve early harvest and get more early yield. This also makes the control of early season vigour easy.

Further researches can be made with low conductivity (1500 µmhos cm^{-1} or lower) mainfeed solutions for the summer to keep the conductivity of the solution less than 3000 µmhos cm^{-1} in perlite bag culture. Since the effect of seedling age varied according to nutritional regimes, further research is needed to evaluate pre and post transplant nutritional regimes. And to keep the fruit craking and blossom-end rot ratio down, beneficial practices should be investigated on tank aeration and greenhouse temperature reduction as well as investigation of varieties resistant to fruit cracking and blossom-end rot.

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