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Ahmad Alhariri
Department of Horticulture, Faculty of Agriculture, Damascus University, Damascus, Syria

M Boras
Department of Horticulture, Faculty of Agriculture, Tishreen University, Lattakia, Syria

Corresponding Author:
Ahmad Alhariri
Department of Horticulture, Faculty of Agriculture, Damascus University, Damascus, Syria

Responses of seed germination and yield related traits to seed pretreatment and foliar spray of humic and amino acids compounds in carrot (*Daucus carota* L.).

Ahmad Alhariri and M Boras

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Abstract
This investigation was conducted at Research Farm and Plant Physiology Laboratory, Faculty of Agriculture, Damascus University to study the effects of some humic compounds and amino acids on seed germination characteristics and some quantitative traits of carrot (Nantes variety). Five commercial organic fertilizers were used (WAF_1, WAF_3, P-Humas, Agro and Acto). The results showed that seed treatments in organic solutions reduced germination time, improved germination uniformity and increased seed vigor. Among all fertilizers WAF_3 1.5 g/l (T_2), consists of amino and organic acids, was significantly superior and recorded maximum germination capacity and germination percentage 62% and 94% respectively, take minimum time for seeds germination 5.2 day, highest homogeneity of seed germination 14.5 seed/day and seed vigor 1.78 g/100 seedling emergence. Field experiment revealed that foliar application of organic fertilizers significantly improved plant growth and roots yield by increasing plant height, plant fresh weight, leaves fresh weight, roots fresh weight and harvest index. Among treatments, Agro 1.5 mL (T_4) "45% organic material in the form of amino acids + (Fe, Mn, S, Zn, B, Cu, Mo)" recorded maximum plant height 43.1 cm, plant fresh weight 143 g, roots fresh weight 111 g and harvest index 77.60%.

Keywords: Carrot, Humic Acid, Amino acids, organic fertilizers, seed germination, yield.

Introduction
Carrot (*Daucus carota* L.) an economically important vegetable crop of family Apiaceae cultivated throughout the globe. The crop is grown on 1.131 M hectares globally, China share more than 35% of which and considered as the first producer of carrot in the world with total production of 18.000.000 MT and yield of 450898 hg/ha in 2018 (carrot and turnip as aggregate data) (FAO, 2020) [13]. As one of the main root vegetable crops, carrot has remarkable nutritional and health value and considered as a rich source of carotenoids, phenolic compounds, polyacetylenes, and vitamins (Rubatzky *et al*. 1999 and Que *et al*. 2019) [27, 26]. The health benefits and public awareness of nutritional health security are positively influencing the demand and consumption of carrot by consumers as well as nutraceutical based industry (Selvakumar *et al*. 2019) [29]. According to recent studies, cultivated carrot originated in the region of central Asia (Afghanistan, Pakistan, and Iran) (Iorizzo *et al*. 2013) [19].
Heterogeneous, asynchronized and lower rates of seed germination are major challenges in *Apiaceae* (*Umbelliferae*) family and have a major impact on final yield and quality especially for vegetable crops established by direct seeding such as carrot and parsley (Mozumder and Hossain, 2013) [21]. Improvement of physiological seed quality and seeds priming treatments to increase seeds longevity, germination speed and homogenous under different field conditions are a major anxiety not only for carrot growers but also for seed agribusiness sector. Recently, different pre-sowing seed treatments have been proposed to improve uniformity, seedling emergence and seed vigour. In general, using organic fertilizers contain Humic and Amino acids increases soil fertility and productivity, increases water holding capacity and enhance seed germination. Humic acid also reduces the other chemical fertilizer requirements, increases aeration of the soil, increases the protein and mineral contents of most crops (Salman *et al*. 2005) [28].

Seed treatments of Pepper (Capsicum annum L.) by soaking in different organic solutions (humic acid and amino acids) 1:5 ratio increased the speed and homogeneity of germination and improved seedling emergence and seed vigour (Hadad *et al*. 2009) [17]. Moreover, foliar spraying of humic substances (Humia acid and Fulvic acid had significant effect on seedling quality, transplanting shock durability, yield and yield related traits of Pepper and Eggplant (Hadad *et al*. 2009 and Azarpour *et al*. 2012) [17, 10] and improved plant growth characters and enhanced the yield, economic yield and harvest index of Carrot (Helaly 2018). Hence the aim of this study was to investigate the effects of seed treatments and foliar application of different humic compounds and amino acids on the germination characteristics and harvest index of Carrot "Nantes variety".

Materials and Methods

This study was conducted at Research Farm and Plant Physiology Laboratory, Faculty of Agriculture, Damascus University in 2017-2018. Carrot "Nantes variety" purchased from local market was used in this study. Five different commercial organic fertilizers namely Acto "65% organic matter in the form of humic acid", Agro "45% organic material in the form of amino acids and proteins in addition to micronutrients (Fe, Mn, S, Zn, B, Cu, Mo)", P- humus "65% organic material in the form of humic acid plus some nutrients (K2O, N, Fe)", WAF_3 "31% organic material in the form of humic and amino acids plus 8% Fe" and WAF_1 "30% organic material in the form of amino acids" were used.

Seed treatments

Seeds were soaked in solutions of different fertilizers (Table 1) for 24h with seeds to solution ratio 1:5. Hundred seeds with four replications for each treatment were placed on two layers of filter paper moistened with 5 ml of distilled water in covered 9 cm Petri dishes. Petri dishes were subsequently kept in the dark, at 25 °C. Germination was monitored every day for 14 days, and the seeds were counted when they exhibited a radicle extension of ≥ 2 mm. The following germination parameters were determined following Al-Mudaris (1998) [3].

1. Germination Capacity (Pre- germination percentage) (GC) = the total seeds germinated at pre- counting day/number of initial seeds used 100 times.
2. Final germination percentage (G) = the total seeds germinated at end of trial/number of initial seeds used 100 times.
3. Mean Germination Time (MGT) = ΣFx/ΣF; where F is the number of seeds germinated on day x.
4. Germination Homogenous (GH) = the total seeds germinated at end of trial/the number of actual germination days.
5. Seed Vigor (SV) = fresh weight of 100 seedlings shoot in the 10th day of germination.

Field experiment

Field experiment was laid out in a randomized block design (RBD). There were six treatments (Table 1) with three replications (18 unit plots 1m × 1m). Seeds were sown in lines about 1.5 cm depth and covered with loss soil. The uniform irrigation was given at every interval (5-6 days) to each plot. Thinning was done after seedling emergence to maintain spacing of 20 cm x 10 cm. Applications of different treatments started after emergence of first true leaf (4 sprays @ 15 days interval). The data on growth and yield was recorded at the crop harvest.

SPSS (Arbuckle, 2010) [4] was used to perform a descriptive analysis based on means of each parameter. One-way ANOVA was used to compare means of appropriate experimental treatments and the significance of difference between pair of means was tested by the least significant difference (LSD) test at 5% levels of probability (Gomez and Gomez, 1984) [15].

Table 1: Seeds and field treatments

Seeds treatments			Field treatments		
Treatment code	**Treatment type soaking for 24h**	**Concentration**	**Treatment code**	**Treatment type foliar spray**	**Concentration**
Control	**Dry seeds**	**-**	**Control**	**-**	**-**
T_1	Distilled water	-	T_1	WAF_1	1.5 g/l
T_2	WAF_1	1.5 g/l	T_2	WAF_3	1.5 g/l
T_3	WAF_3	1.5 g/l	T_3	P- humus	1 g/l
T_4	P- humus	1 g/l	T_4	Agro	1.5 mL
T_5	Agro	1.5 mL	T_5	Acto	1 mL

Results and discussion

Effect of different seed treatments on germination characteristics

Analysis of variance showed that there are significant differences between seeds treatments on germination characteristics. The results depicted in Table 2. showed that germination capacity (GC%), germination percentage (G%), mean germination time (MGT), germination homogenous (GH) and seed vigor (SV) were significantly enhanced in all seed treatments over control. Maximum germination capacity (GC%) was recorded in seeds treated with WAF_3 (T_3) 62%, it was followed by Agro (T_5) 60% and P- humus (T_4) 59% and minimum of (GC%) was for seeds soaked in distilled water (T_1) 47%, whereas dry seeds (control) showed 34% as an average germination capacity (GC%). Highest germination percentage (G%) were observed for seeds soaked in WAF_3 solution (T_3) 94%, followed by Agro (T_5) 90% and P- humus (T_4) 89% and minimum of germination percentage (G%) was for seeds treated with WAF_1 (T_2) 86% against un treated seeds (control) 83%. Significant variation was also observed in case of mean germination time (MGT). Seeds treated with different solutions germinated faster than untreated seeds (control), WAF_3 (T_3) gave best performance in (MGT) 5.2 days followed by Agro (T_5) 5.7 days and WAF_1 (T_2) 6.1 days while seeds treated with distilled water (T_1) and dry seeds (control) take longer time to germinate 6.7 and 8.2 days respectively. Moreover, seeds soaked in WAF_3 (T_3) for 24 h showed highest germination uniformity with (GH) 14.5 seed\day followed by WAF_1 (T_2) 12.8 seed\day and Agro (T_5) 12.2 seed\day, while lowest germination homogenous (GH) observed for dry seeds (control) 10.3 seed\day and distilled water treatment (T_1) 10.6 seed\day. Seed vigour index (SV) followed the similar trend and it ranged from 0.75 to 1.78 g. the greater seed vigour (SV) was found in case of WAF_3

treatment (T_3) 1.78 g, in contrast distilled water treatment (T_1) and dry seeds (control) gave the lowest seed vigour index 1.12 and 0.75 g respectively.

The results of this experiment showed that seed treatments by soaking in Humic and Amino Acids fertilizers solutions for 24 h enhanced all germination parameters in Carrot. This might due to activation - at embryonic level - of those metabolic and enzymatic processes, increased water and nutrient uptake capacity that may assure a better and more immediate development of the embryo and quicker establishment (Abdul-baki 1988, Piccolo *et al*. 1993 and Boras and Al. Ouda 2003) [2, 25, 5]. These results were in conformity with those of Gadimov *et al*. (2007) [14] on peas, Hadad *et al*. (2009) [17] on sweet pepper and Wali *et al*. (2019) [33] on wheat about effect of seed treatments with humic substances on germination characteristics.

Table 2: Effects of humic and amino acids solutions on germination parameters of carrot seeds.

Treatments	Germination Capacity (GC %)	Germination percentage (G %)	Mean Germination Time (MGT)	Germination Homogenous (GH seed\day)	Seed Vigour (SV) g/100 plant
Control	34^{d}	83^{e}	8.2^{a}	10.3^{d}	0.75^{e}
T_1	47^{c}	87^{cd}	6.7^{b}	10.6^{d}	1.12^{d}
T_2	57^{b}	86^{d}	6.1^{d}	12.8^{b}	1.49^{b}
T_3	62^{a}	94^{a}	5.2^{f}	14.5^{a}	1.78^{a}
T_4	59^{ab}	89^{bcd}	6.4^{c}	11.6^{c}	1.45^{b}
T_5	60^{ab}	90^{bc}	5.7^{e}	12.3^{bc}	1.28^{c}
P value	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
LSD 5%	3.5	3.1	0.2	0.8	0.14

Different superscripts in the same column represent significant differences between treatments (P< 0.05)

Effects of foliar application of organic fertilizers on growth and yield of carrot

The effects of foliar spray of different concentration of humic and amino acids substances on plant growth and yield of carrot are reported in Table 3. The results revealed that foliar application of humic and amino acids organic fertilizers improved plant growth and yield as indicated by increased plant height, plant fresh weight, leaves fresh weight and roots fresh weight. Plant height was significantly affected by different types of fertilizers and ranged from 30.6 to 43.1 cm. The maximum plant height was achieved in Agro (T_4) and the minimum plant height recorded for untreated plants (control). There were significant differences among treatments for plant fresh weight, the greater plant fresh weight was reported in Agro (T_4) 143 g followed by WAF_3 (T_2) 130 g and Acto (T_5) 110 g, while lesser plant fresh weight was recorded in control 75 g. Moreover, foliar spray of organic fertilizers significantly increased leaves and roots average fresh weight against untreated plants (control).

Plants treated with Acto (T_5) showed highest leaves fresh weight 40 g, while control plants registered lowest average leaves fresh weight 30 g. For average fresh root weight, plants treated with Agro (T_4) performed maximum average fresh root weight 111 g followed by WAF_3 (T_2) 95 g and WAF_1 (T_1) 71 g. However, untreated plants (control) had the minimum average of fresh root weight 45 g.

Harvest index (HI) or migration coefficient is the proportion of root yield to the total plant biomass and it is an indication of coefficient of effectiveness of carrot root production in relation to total biological yield. The data demonstrated that foliar application of humic and amino acid fertilizers had considerable effect on harvest index (Fig. 1).

It was observed that highest harvesting index recorded in Agro treatment (T_4) 77.60% and the next rank was occupied by WAF_3 (T_2) followed by Acto (T_5) 73.10% and 70% respectively. Whereas**,** the lowest harvesting index was noticed in untreated plant (control) that is 60%. This results indicate that foliar application of humic and amino acids organic fertilizers significantly improved biological and roots yield of carrot. Our findings were in agreement with those reported by Muscolo *et al*. (2007) [23], Grabowska *et al*. (2013) [16] and El-Helaly, (2018) [12] in carrot, Hadad *et al*. (2009) [17] in sweet pepper, Türkmen *et al*. (2014) [32] and Abdellatif *et al*. (2017) [1] in tomato. Foliar application of humic substances induced the same effect of IAA in improving carrot cell growth (Muscolo *et al*. 2007) [23]. Humic acid fertilizers significantly affect plant development in different ways, with significant influence not only on the yield but mainly on growth and quality parameters. Appreciated effects of humic substances can be described as an interaction between these fertilizers and plant physiological and metabolic processes (Muscolo *et al*. 1999 and Nardi *et al*. 2002) [22, 24].

Moreover, humic fertilizers enhance nutrient uptake (Piccolo *et al*. 1993, Muscolo *et al*. 1999) [25, 22], increasing cell membrane permeability, oxygen uptake, respiration and photosynthesis and regulate mechanisms and enzymatic activity involved in plant growth stimulation (Canellas *et al*. 2002, Chen *et al*. 2004, Dobbss *et al*. 2007 and Canellas *et al*. 2014) [6, 8, 9, 7]. Incorporation of humic acids, amino acids and micronutrients enhanced growth and root yield of carrot.

The results of recent reports suggested that seed treatment and foliar application of amino acid based fertilizers had positive impact in growth and yield of tomato (Koukounaras *et al*. 2013) [20] and accumulation of dry matter, chlorophyll in soybean (El-Aal *et al*. 2018) [11] starch, and polysaccharides in bean (SH Sadak *et al*. 2014) [30].

Table 3: Effects of foliar application of organic fertilizers on growth and yield components of carrot.

Treatments	Plant height (cm)	Plant fresh weight (g)	Leaves fresh weight (g)	Roots fresh weight (g)
Control	30.6^{e}	75^{e}	30^{c}	45^{d}
T_1	34.2^{d}	105^{cd}	34^{b}	71^{c}
T_2	40.7^{b}	130^{b}	35^{b}	95^{b}
T_3	36.3^{c}	100^{d}	35^{b}	65^{c}
T_4	43.1^{a}	143^{a}	32^{bc}	111^{a}
T_5	32.5^{de}	110^{c}	40^{a}	70^{c}
LSD 5%	2.4	9	3.7	9.1

Different superscripts in the same column represent significant differences between treatments (P< 0.05)

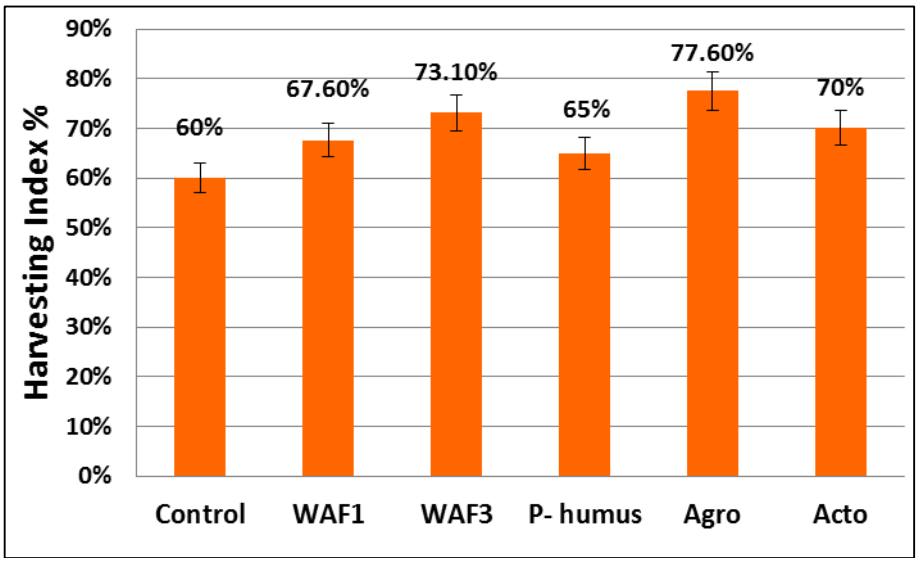

Fig 1: Effects of organic fertilizers on harvest index (HI)

Conclusion

The present investigation demonstrated that carrot seed treatments with different humic and amino acids fertilizers enhanced germination characteristics by increasing germination capacity and percentage, reducing germination time, improving homogeneous of germination and seed vigor. However, among organic fertilizer treatments WAF_3 "31% organic material in the form of humic and amino acids + 8% Fe" showed the best effects in all germination parameters. Furthermore, foliar application of humic and amino acids organic solutions significantly improved plant growth and increased roots yield and harvesting index. Among treatments, plants treated with Agro "45% organic material in the form of amino acids + (Fe, Mn, S, Zn, B, Cu, Mo)" had best performance in terms of plant growth, roots yield and migration coefficient.

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