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Performance assessment of mint on growth and yield attributes supplied with three nutrient combinations under two modified nutrient film technique (NFT)

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Abstract
This study was conducted to examine the performance of mint in modified Nutrient film technique (NFT) hydroponic systems under two models *viz.*, Horizontal (S_1) and Vertical A types (S_2) and three nutrient combinations *viz.*,T_1-NPK@ 40:65:40 / hectare, T_2-NPK @ 50:75:50/hectare,T_3-NPK@60:85:60/hectare were tested. The experiment was laid out in Factorial Randomized Block Design (FRBD) with three replication at the Department of Vegetable Science on Tamil Nadu Agricultural University. The observations *viz.*, yield(Kg/plant), leaf area(cm^2), Leaf area index (LAI), Leaf area duration (LAD-days), Leaf chlorophyll content (LCC-SPAD Value),Specific leaf area (SLA-cm^{2}g^{-1}),Net assimilation rate(NAR-gg^{-1}day^{-1}), Relative growth rate (RGR-gg^{-1}day^{-1}),Crop growth rate (CGR-gm^{-2}day^{-1}) were determined. The nutrient quantities were computed for 100 litre of water and were given through fertigation. The pH 6.5-6.8 and EC around 2 dS m^{-1} was continuously maintained throughout the trial period. It was concluded from the study that (S_2T_1) vertical A type with nutrient combinations of NPK @ 40:65:40 / hectare have recorded highest for yield and growth parameters such as Leaf area, NAR, RGR, CGR, LAI when compared to other treatments. Lowest yield and other growth attributes was recorded in S_1T_3 Horizontal type with combination of NPK @ 60:85:60 /ha.

Keywords: Hydroponics, NFT**,** Yield**,** Net assimilation rate, Relative growth rate, Crop growth rate

1. Introduction
Hydroponics is a method of growing plants in nutrient solutions along with inert medium like clay pebbles. Hydroponics is derived from Greek word meaning "hydro" means water and "ponos" means labour (Douglas JS 1975). In this system plants were allowed to expose their roots in nutrient solution throughout their growth period. Therefore nutrient solution should contain all the seventeen basic elements which includes both macro and micro nutrients required for plant growth. According to growers hydroponics system are effortless as they do not require cultural practices such as weeding, ploughing, crop rotation which were followed in conventional method. Hughes *et al*. (2007) reported that these system helps in continuous supply of production of vegetables in short period of time in a small space with controlled environmental condition.
The nutrient film technique (NFT) was developed by Dr. Allan Cooper during the late 1960s at England (Winsor *et al.* 1979). NFT emerged to be the most evolving type, a thin film of nutrient solution flows through plastic PVC pipes or channels in which the nutrient pump pushes the water from hydroponic reservoir to growing tray as thin film of solution and flows through gravity to dangling roots of plant from where the plants takes their nutrients. Catchment pipes with nutrient solution is monitored continuously for replenishment of solutions before it is drain out reported by Domingues *et al.* (2012) [17]. Capillary material in the channel prevents young plants from drying and it helps the roots to grow as tangled mat. In NFT hydroponics, it is important to consider the following factors such as temperature, pH and EC of solution should be maintain between 13 and 15°C. If this range is decreased it reduces the absorption of the nutrients. pH must be in the range of 5.5 to 6.5, electrical conductivity (EC) should be in the range of 1.5 to 3 d S m^{-1} these range provides all nutrients and the channels should have a slope of 1.5% to 2% (Wortman, 2015) [21].

2. Materials and Methods
The trial was laid out at Factorial Randomized Block Design (FRBD) with three replication at

the Department of Vegetable Science; Horticultural College and Research Institute, TNAU which is located at latitude of N 11°0'34.9596" and longitude of E 76°55'50.22122" during 2020-2021. Terminal cuttings of length 15 cm were prepared and planted in pro trays filled with coir pith. After fourth true leaf stage, the cuttings were transplanted along with the ball of earth into modified NFT structures *viz.*, modified NFT's vertical A-type and horizontal.

G- Growing systems	N - Nutrient combinations
S_1- Horizontal type	T_1-NPK@ 40:65:40 per hectare
S_2- Vertical A type	T_2-NPK @ 50:75:50per hectare
	T_3-NPK @ 60:85:60 per hectare

Observation (Table1) were according with Estrada and González (2008) [3].

Table 1: List of parameters measured with units

Index	Description	Formula	Units
LAI	Leaf area index	LA/P	-
LAR	Leaf area ratio	LA/TPDM	Cm^2/g
SLA	Specific leaf area	LA/LDW	Cm^2/g
LAD	Leaf area duration	L1+L2/2*(t2-t1)	days
NAR	Net assimilation rate	(W2-W1)(logL2-logL1)/(t2-t1)(L1-L2)	$g\ g^{-1}day^{-1}$
RGR	Relative growth rate	Logw2-Logw1/(t2-t1)	$g\ g^{-1}day^{-1}$
CGR	Crop growth rate	NAR*RGR	$g\ m^{-2}\ day^{-1}$
LA-leaf area; p-spacing; TPDM-total plant dry matter; LDW-leaf dry weight; W1,W2-whole plant dry weight;L1,L2-leaf area index			

3. Result and Discussion

3.1 Leaf chlorophyll content (LCC)

Leaf chlorophyll content is directly associated with the capacity and efficiency of the photosynthetic tools and hence it provides valuable information on photosynthetic prospective. Lin *et al*. (2013) [20] reported that leaves is a very essential to compute the chlorophyll because when leave degrades its colour change from a bright green to other colours (brown orange, yellow, and purple) this change of colour indicate that loss of products quality. Statistical analysis revealed that maximum chlorophyll content (32.47) was recorded at S_2T_1 Vertical A type-NFT with nutrient combination of NPK@ 40:65:40 / ha Coronel *et al*. (2011) [16] reported that when plants have adequate nutrients like N, Mg, Fe and Mn they content higher value of chlorophyll as it is directly related to efficiency of photosynthetic rate. The chlorophyll content was minimum (16.67) in S_1T_3 Horizontal type with combination NPK @ 60:85:60/ha. Castillo and Ligarreto,2010 stated that chlorophyll content in plants is closely related to the N content and, therefore, while minimum chlorophyll content of the plant may indicate that nutrient content is deficit. There exist a variations among treatments and systems and their interaction (NXG) also showed significant difference (Table 1 & Fig.1).Chlorophyll content was also found to be directly related to nitrogen status, considering that most of the leaf nitrogen is integrated with chlorophyll. The Soil Plant Analysis Development (SPAD) most frequently used diagnostic tool to determine the content of chlorophyll in plants Barrios *et al*. (2011) [15]. Richardson *et al.* 2002 [12] reported that nitrogen status cannot be directly accessed by measure of chlorophyll content as a result the rate of nitrogen fertilization can be adjusted by the information obtained.

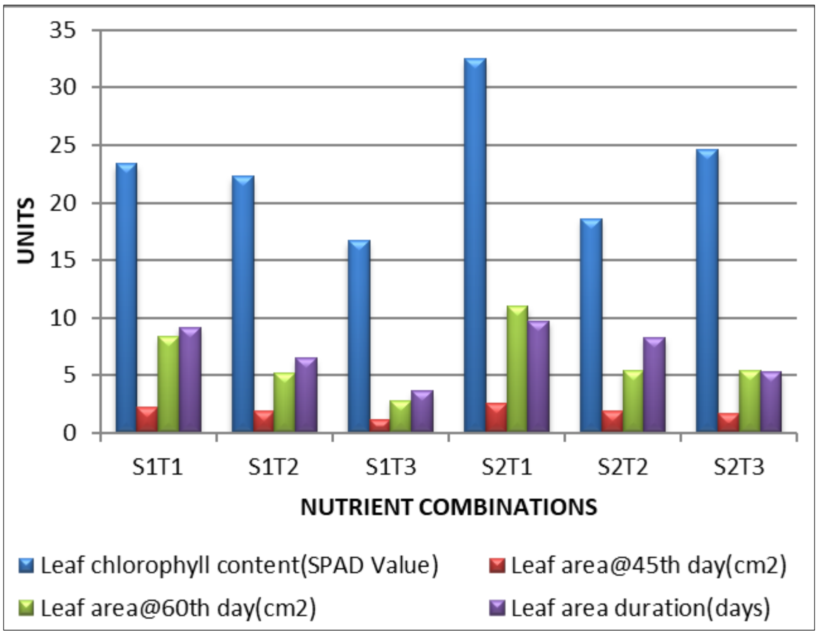

Fig 1: Influence of different NFT systems and three different nutrient combinations on Leaf chlorophyll content (LCC), Leaf area(LA), Leaf area duration(LAD)

3.2 Leaf area (LA)

Leaf area is directly proportional to photosynthesis and production of dry matter i.e. increases in leaf area increases the rate of photosynthesis capacity of the plant. So that plants put a major share of photosynthetic energy to produce leaf. The statistical analysis on leaf area on 45th day [Table 2 &

Fig.1] confessed that there is a significant difference among treatments and systems and their interaction effect also observed to be significant. The maximum leaf area was recorded at S_2T_1 (Vertical A type-NFT) along with treatment NPK@ 40:65:40/ha (2.61cm^2), minimum leaf area was recorded at S_1T_3 Horizontal type with NPK @ 60:85:60 /ha (1.19cm^2) Brown, R. H. *et al*. (1984) [4] findings reported that decline in leaf area may be due to no new leaves is formed during reproductive stage and abscission of leaf is more also it is faster than formation of new leaves. Maximum and minimum Leaf area was accord with same treatment (10.97cm^2) and S_1T_3 (2.83cm^2) on 60th day respectively.

3.3 Leaf area index (LAI)

The leaf area index (LAI) it is a measure of the photosynthetic active area it is an important parameter in plant ecology as it links canopy structure with ecosystem function. Data on leaf area index (Table 3 & Fig.5) showed there is a significant variation existed between their (NXG) effect and treatments. The S_2T_1 Vertical A type-NFT with the nutrient combinations of NPK @ 40:65:40/ha showed highest value 0.0017 for LAI at 45th day. Increase in the LAI depends on nutrition, temperature, the interception of radiation and water availability stated by Hernandez and Soto, 2012. Lowest LAI (0.0007) was recorded atS_1T_3 horizontal type with NPK @ 60:85:60/hectare. On 60th day Maximum LAI (0.0068) in Vertical A type S_2T_1 -NFT with the nutrient combinations of NPK@ 40:65:40 / ha, lowest LAI at 60th day (0.0018) was recorded at horizontal type S_1T_3 with NPK @ 60:85:60/ha.

3.4 Yield

By statistical analysis on (Table 2 & Fig.5) yield parameter existed a significant difference between treatments and systems. Their interaction effect (NXG) showed a significant difference. Yield is more in Vertical type because soil grown plants seeks out lot of energy to their food source but plants grown under hydroponics are given with exactly what they needed so they direct all their energy for producing higher yield. The maximum yield (0.35 Kg/plant) was recorded on (Fig.2) S_2T_1 Vertical A type-NFT with the nutrient NPK@ 40:65:40/ ha. Lowest yield was recorded at Fig.3 S_1T_3 (0.1 Kg/plant) with NPK @ 50:75:50/ha.

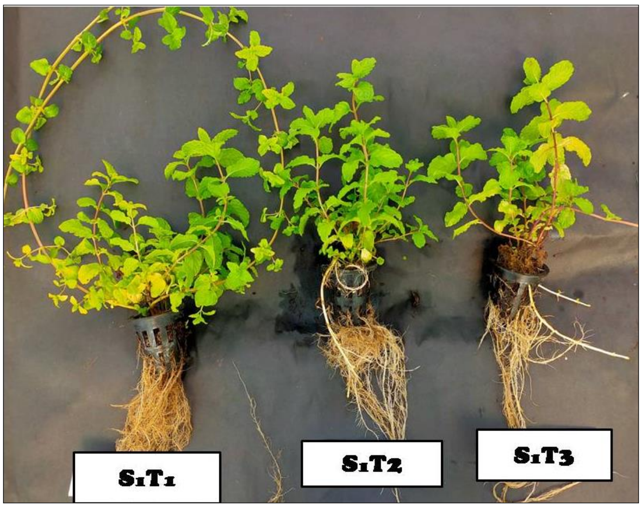

Fig 2: Comparative performance of mint on horizontal type (S_1) along with three nutrient combinations *viz.,* T1-NPK@ 40:65:40/ha, T2- NPK @ 50:75:50/ ha, T3-NPK @ 60:85:60 /ha

Fig 3: Comparative performance of mint on vertical A type (S_2) along with three nutrient combinations *viz.,* T1-NPK@ 40:65:40/ha, T2- NPK @ 50:75:50/ ha, T3-NPK @ 60:85:60 /ha

3.5 Leaf area duration (LAD)

Leaf area duration long term relationship of LAI. Power *et al.* (1967) [2] integrated that LAI with time and called as Leaf Area Duration. LAD takes both the duration and also about extent of crop canopy. Among leaf are duration existed a significant variations among different treatments for leaf area duration and there interaction (NXG) effect also showed significant difference. The S_2T_1 show maximum leaf area duration (9.71 days) at Vertical A type-NFT with nutrient combination of NPK@ 40:65:40/ha, the least LAD (5.27days) was observed in S_1T_3 NPK @ 60:85:60/hectare (Table 2 & Fig.1).

3.6 Leaf area ratio (LAR)

There existed significant difference on leaf area ratio by statistical analysis showed that there is a significant difference between treatments for leaf area ratio (Table 3 & Fig2). The maximum value for leaf area ratio at 45th day (0.51 $cm^{-2}g^{-1}$day) was recorded on S_2T_1 Vertical A type-NFT with the nutrient NPK@ 40:65:40/ ha, lowest value for leaf area ratio (0.16 $cm^{-2}g^{-1}$day) was recorded at S_1T_3 with NPK @ 50:75:50/ha. Similar trend was continued on 60th day of leaf area ratio also S_2T_1 (1.27 $cm^{-2}g^{-1}$day) and S_1T_3 (0.2$cm^{-2}g^{-1}$day) were recorded maximum and minimum leaf area ratio correspondingly.

3.7 Specific leaf area (SLA)

Kvet *et al.* (1971) states that Specific leaf area it is a measure of the leaf area of the plant to leaf dry weight. Specific leaf area statistical data revealed that there existed significant variations between different treatments and systems for specific leaf area. The maximum value (3.04cm^2g^{-1}) was recorded at S_2T_1 Vertical A type-NFT with nutrient combination of NPK@ 40:65:40 /ha, lowest specific leaf area value (0.73 cm^2g^{-1}) was recorded in S_1T_3 horizontal type with NPK @ 60:85:60/ha (Table 4 & Fig.4).

3.8 Net assimilation rate (NAR)

Data on (Table 4 & Fig.4) for Net assimilation rate showed that there existed significant variations among different treatments. The maximum net assimilation rate (0.15g $g^{-1}day^{-1}$) was recorded at S_2T_1 Vertical A type-NFT with combination of NPK@ 40:65:40 / ha. The NAR is an indirect measure that determines the photosynthetic efficiency of plants. NAR is directly related to the leaf area, layout and age of the leaves and also affects the internal metabolism of the plant as a response to external factors throughout the respiration process (Torres- Moya *et al*.,2016) [23]. Dry matter accumulation rate per unit of leaf area is net assimilation rate (NAR). As plants grow NAR decreases during the growing season, decrease in NAR with plant age results in lower photosynthetic activity. Decrease in NAR generally associated with increased foliage in the plants, making the intercepted light lower (Evans and Poorter, 2001) [11]. In this study also S_1T_3 horizontal type with nutrient combination NPK @ 60:85:60/ha show decreased NAR (0.04 g g $^{-1}$day^{-1})

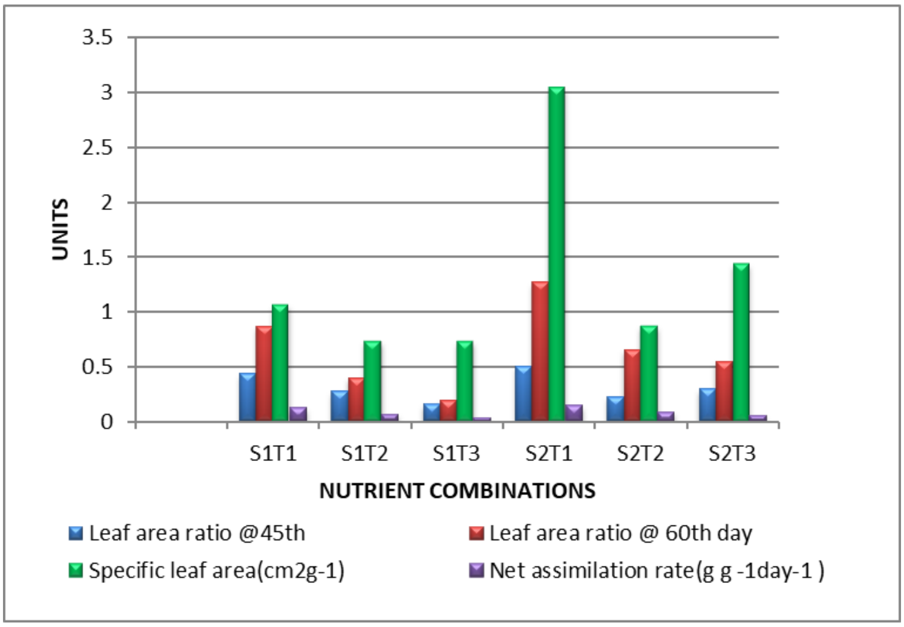

Fig 4: Influence of different NFT systems and three different nutrient combinations on Leaf area ratio (LAR), Specific leaf area(SLA), Net assimilation rate(NAR)

3.9 Relative growth rate (RGR)

Table 4 & Fig.5 showed a significant variations among different treatments for relative growth rate. The increased RGR (0.08 g g $^{-1}$day^{-1}) was recorded at S_2T_1 Vertical A type-NFT with nutrient combination of NPK@ 40:65:40 / ha. Relative growth rate was decreased (0.022 g g $^{-1}$day^{-1}) in S_1T_3 horizontal type with treatment NPK @ 60:85:60/ha). Due to a high RGR a plant size will increase rapidly in and may occupy a larger space, both above and below ground. Consequently, such a plant has the opportunity to acquire a larger share in limiting resources like nutrients, light or water than a slower growing individual reported by Grime (2006) [7].

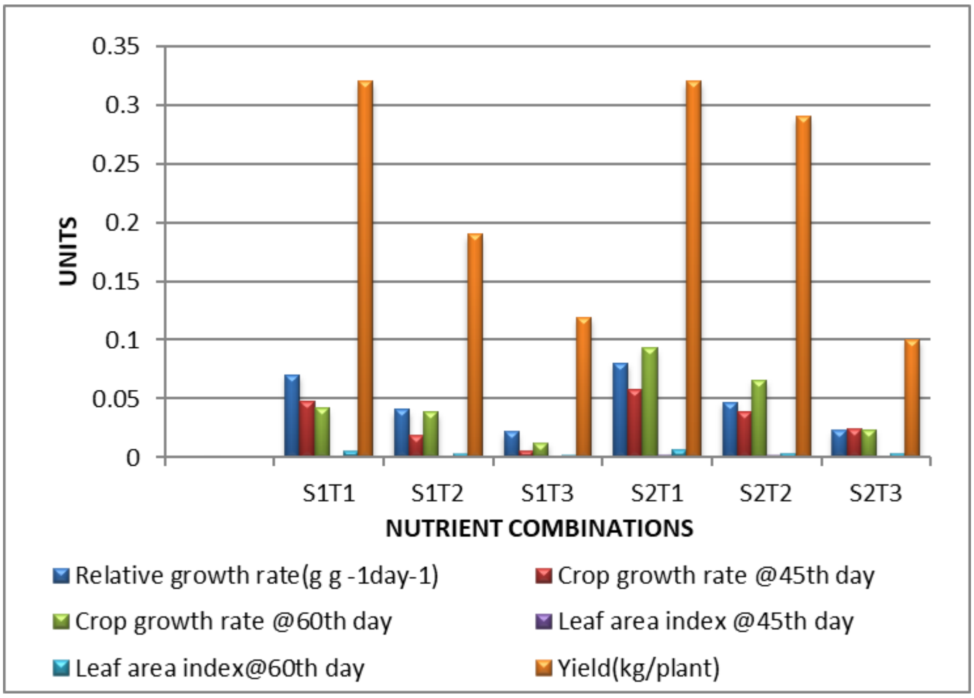

Fig 5: Influence of different NFT systems and three different nutrient combinations on Yield, Leaf area index (LAI), Relative growth rate(RGR), Crop growth rate(CGR)

3.10 Crop growth rate (CGR)

CGR is dry accumulation per unit area of land. The data on (Table 4& Fig.5) highest CGR at 45th day (0.058gm^{-2}day^{-1}) was recorded at S_2T_1 Vertical A type-NFT with the nutrient combinations of NPK@ 40:65:40/ha. Maximum CGR coincides with early fruiting stage and decreases as plant mature. As the crop develops, the leaf area expands and less light penetrates through the crop to soil surface, decreases as plant matures. The lowest value for CGR (0.006g m^{-2} day^{-1}) was recorded at S_1T_3 horizontal type with treatment NPK @ 60:85:60/ha. There existed significant difference on crop growth rate by statistical analysis showed that significant difference between treatments for leaf area. Same result was obtained at 60th day of CGR Vertical A type-NFT (S_2T_1) and horizontal type (S_1T_3) were recorded maximum (0.093gm^{-2}day^{-1}) with the nutrient combinations of NPK@ 40:65:40 / ha, minimum (0.0123 gm^{-2}day^{-1}) with NPK @ 60:85:60/hectare.

Table 2: Influence of different NFT systems and three different nutrient combinations on Yield, Leaf chlorophyll content(LCC), Leaf area(LA), Leaf area duration(LAD)

Nutrient combinations	Yield (kg/plant)			Leaf chlorophyll content (SPAD Value)			Leaf area@45th day (cm²)			Leaf area@60th day(cm²)			Leaf area duration(days)		
S1T1	0.32b			23.37bc			2.2b			8.33b			9.18		
S1T2	0.29cd			22.3d			1.87c			5.23c			6.47		
S1T3	0.1e			16.67c			1.19d			2.83d			3.64		
S2T1	0.35a			32.47a			2.61a			10.97a			9.71		
S2T2	0.19c			18.63d			1.87c			5.38c			8.28		
S2T3	0.12d			24.58b			1.67c			5.47c			5.27		
	G	N	GXN	G	N	GXN	G	N	GXN	G	N	GXN	G	N	GXN
S.Ed	0.004	0.005	0.007	0.563	0.689	0.975	0.065	0.079	0.112	0.0371	0.455	0.644	0.483	0.591	0.836
CD(0.05)	0.009**	0.011**	0.016**	1.255**	1.537**	2.174**	0.145**	0.177**	0.251*	0.828**	1.014**	1.434*	1.076*	1.31**	NS

G-Growing conditions, N-Nutrient combination, GXN-Interaction effect, NS-Non significant
Two systems *i.e.* Horizontal type (NFT)-S1, Vertical A type (NFT) –S2 and with three nutrient combinations *viz.*, T1-NPK@ 40:65:40/ha, T2-NPK @ 50:75:50/ ha, T3-NPK @ 60:85:60 /ha

Table 3: Influence of different NFT systems and three different nutrient combinations on Leaf area ratio (LAR), Leaf area index(LAI),Specific leaf area (SLA)

Nutrient combinations	Leaf area ratio @45th (cm⁻²g⁻¹day)			Leaf area ratio @ 60th day (cm⁻²g⁻¹day)			Leaf area index @45th day			Leaf area index@60th day		
S1T1	0.44			0.87			0.0013b			0.0052b		
S1T2	0.28			0.4			0.0012c			0.0032c		
S1T3	0.16			0.2			0.0007e			0.0018d		
S2T1	0.51			1.27			0.0017a			0.0068a		
S2T2	0.23			0.66			0.0016c			0.0033c		
S2T3	0.3			0.55			0.00104d			0.0034c		
	G	N	GXN	G	N	GXN	G	N	GXN	G	N	GXN
S. Ed	0.03	0.04	0.05	0.05	0.06	0.08	0.00003	0.00004	0.00006	0.00023	0.00028	0.00040
CD(0.05)	NS	0.08**	NS	0.104**	0.181**	NS	0.00007**	0.00009**	0.00012**	0.00052**	0.00063**	0.00090*

G-Growing conditions, N-Nutrient combination, GXN-Interaction effect, NS-Non significant
Two systems *i.e.* Horizontal type (NFT)-S1, Vertical A type (NFT) –S2 and with three nutrient combinations *viz.*, T1-NPK@ 40:65:40/ha, T2-NPK @ 50:75:50/ ha, T3-NPK @ 60:85:60 /ha

Table 4: Influence of different NFT systems and three different nutrient combinations on Specific leaf area (SLA), Net assimilation rate(NAR), Relative growth rate (RGR), Crop growth rate(CGR)

Nutrient combinations	Specific leaf area(cm²g⁻¹)			Net assimilation rate(g g⁻¹day⁻¹)			Relative growth rate(g g⁻¹day⁻¹)			Crop growth rate @45th day (g m⁻² day⁻¹)			Crop growth rate @60th day (g m⁻² day⁻¹)		
S1T1	1.07			0.13b			0.07			0.0473			0.042c		
S1T2	0.73			0.07c			0.041			0.0187			0.0387cd		
S1T3	0.74			0.04e			0.022			0.006			0.0123e		
S2T1	3.04			0.15a			0.08			0.058			0.093a		
S2T2	0.87			0.09d			0.047			0.039			0.066b		
S2T3	1.44			0.06de			0.023			0.024			0.0237de		
	G	N	GXN	G	N	GXN	G	N	GXN	G	N	GXN	G	N	GXN
S. Ed	0.198	0.242	0.343	0.005	0.007	0.009	0.006	0.007	0.010	0.004	0.005	0.007	0.004	0.005	0.007
CD(0.05)	0.44**	0.54**	0.765**	NS	0.015**	0.021**	NS	0.016**	NS	0.009**	0.011**	NS	0.009**	0.012**	0.017**

G-Growing conditions, N-Nutrient combination, GXN-Interaction effect, NS-Non significant
Two systems *i.e.* Horizontal type (NFT)-S1, Vertical A type (NFT) –S2 and with three nutrient combinations *viz.*, T1-NPK@ 40:65:40/ha, T2-NPK @ 50:75:50/ ha, T3-NPK @ 60:85:60 /ha

4. Conclusion

Among the two models of modified NFT studied with three nutrient combinations T_1-NPK@ 40:65:40 / hectare, T_2-NPK @ 50:75:50/hectare, T_3-NPK@60:85:60/hectare it was concluded that Vertical A type NFT system supplied with nutrients T_1-NPK@ 40:65:40 / hectare consequently reported to be highest for both yield and other growth parameters such as Leaf area, LAI, CGR NAR, RGR were obtained to maximum in this model. It is important to know the nutrient response of each cultivar. Hence from this experiment inferred that (S_2T_1) vertical A type with nutrient combinations of NPK @ 40:65:40 / hectare is the alternative novel method for cultivation of mint because plants grown in soil use lots of energy to seek out their food while in hydroponically grown plants are given exactly what they need so they direct all their energy into producing higher yield.

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