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Evaluation of water spinach (*Ipomea aquatica* Forsskal) genotypes under vertical farming (wall culture)

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Abstract
An investigation to evaluate different genotypes of water spinach under vertical farming (wall culture) was conducted during *kharif* 2018 on office building wall at Centre of Excellence on Protected Cultivation and Precision Farming, I.G.K.V., Raipur, Chhattisgarh. The 18 genotypes viz. IGWS-1, IGWS-2, IGWS-3, IGWS- 4, IGWS-5, IGWS-6, IGWS-7, IGWS-8, IGWS-9, IGWS-10, IGWS-11, IGWS-14, IGWS-15, IGWS-16,
IGWS-18, IGWS-19, IGWS-20 and IGWS-25 which were collected from different areas of Chhattisgarh were selected for evaluation under wall culture for various parameters like vine length, vine weight, internodal length, number of nodes per vine, leaf length, leaf width, petiole length, dry matter percentage, moisture percentage, fresh weight of leaves, dry weight of leaves, leaf: vine ratio, number of cuttings per month and yield in kg/m^2. The genotypes were also studied for their characteristic features like vine colour, leaf outline, leaf lobe type, number of leaf lobes, shape of central lobes, mature leaf size and mature leaf colour. Studies regarding cost economics of the genotypes were also carried out to find out the most suitable genotypes for wall culture. Organoleptic observations were recorded for each genotype separately as green leafy salad, cooked bhanji and as pakora with gram flour to find out genotype which is excellent in terms of taste. The experiment was carried out on wall frame with 216 panels. 18 genotypes were distributed randomly in 4 replications which consisted of 3 pots and total of 6 plants in each. From the results of the experiment it can be concluded that vertical farming is an economically feasible option for cultivation of leafy vegetables like water spinach, IGWS-2 proved to be the most suitable genotype for cultivation under wall culture since it has high yield attributing characters, attractive in appearance and also excellent in organoleptic characteristics. The produce was free from any contamination from liver fluke which was reported many times in Chhattisgarh due to cultivation of water spinach in marsh and swampy areas.

Keywords: Vertical farming, wall culture, organoleptic, water spinach

1. Introduction
It is expected that by 2020, the world's urban population is to be almost 10 billion. To feed such a massive population is a challenging task, also industrial development and urbanization leads to loss of arable lands day by day. The quality of land is also reducing due to intensive use of agricultural chemicals. For combating such issues, it is important to reduce dependency on arable lands for food production, and for which vertical farming or wall culture is best option. Vertical farming can play a major role in future protection which can face shortages of food due to reduced arable lands and increased population. It can also help in year round production of crops especially leafy vegetables with reduced water usage. It is less affected by unfavorable weather conditions, helps in increased production per unit area and also human and eco friendly. Vertical farming is a practice of growing crops in vertically stacked layers or integrated in other structure (walls or old warehouses) with use of less water and soil. Vertical farming as a concept was developed in the recent years (1999) through the advances in technology by Dickson Despommier at Columbia University. He also explained how hydroponics crops can be grown on upper floor and the lower floors would be suited for chickens and fish that eat plant wastes. Vertical farming can also result in less deforestation, erosion and flooding, unused properties can be used productively, crops can be protected from adverse climatic conditions, less CO_2 emission and water can be used more productively.

In Chhattisgarh, water spinach is grown in three well known Agro-climatic zones, i.e. Northern hills, Chhattisgarh plains and Bastar plateau. It is cultivated in many districts like Dhamtari, Bastar, Raipur, Narayanpur, Kondagaon, Bijapur, Mahasamund, Kanker, Griyabandh, Bilaspur, Ambikapur, and few parts of other districts. Even after such popularity there are only few varieties released in the state and no improved varieties are there. The cultivators rely upon the local genotypes, collect them from ponds and directly sell it to market. One more major problem which the crop is facing against its preference by the consumers is the practice of growing it in swampy and water stagnant area which is followed by most of the cultivators. If harvested from contaminated areas, and eaten raw, water spinach may transmit *Fasciolopsis buski*, an intestinal fluke parasite of humans and pigs, causing fasciolopsiasis, which is reported many times in Chhattisgarh. Vertical farming can play a major role in avoiding such contamination since it produces healthy, contamination free and nutritious produce.

2. Objective of the Study

The objective of the study was to find out water spinach genotypes suitable for vertical farming (wall culture) in terms of economic feasibility, organoleptic characteristics and yield attributing characters.

3. Materials and Methods

The experiment was carried out during *kharif* 2018 on office building wall at Centre of Excellence on Protected Cultivation and Precision Farming, Department of Vegetable Science, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh. 18 genotypes *viz*. IGWS-1, IGWS-2, IGWS-3, IGWS-4, IGWS-5, IGWS-6, IGWS-7, IGWS-8, IGWS-9, IGWS-10, IGWS-11, IGWS-14, IGWS-15, IGWS- 16, IGWS-18, IGWS-19, IGWS-20 and IGWS-25 were selected. The wall structure was prepared with 216 panels and each genotype was replicated 4 times which consisted of 3 pots with 2 plants in each i.e. each replication consisted of 6 plants. The design employed was completely randomized design. The observations were recorded on all 6 plants from each replication and later averaged. The data was analyzed under ANOVA for completely randomized design. The characterization of the genotypes was done on the basis of guidelines depicted in CIP, AVRDC IBPGR Descriptor for Sweet Potato, Z. Huaman. Cost economics was worked out to calculate B: C ratio for each genotype separately using following formula:-

$$\text{Benefit: cost ratio} = \frac{\text{Net return}}{\text{Total cost of cultivation}}$$

The organoleptic observations were recorded by tasting the genotypes as green leaf salad, as cooked bhanji and as pakora (with gram flour). The ratings were given to each genotype from 0 to 5 and later averaged.

4. Results and Discussions

4.1 Mean performances of genotypes

The genotypes were evaluated under various parameters like vine length, vine weight, internodal length, number of nodes per vine, leaf length, leaf width, petiole length, dry matter percent, moisture percent, fresh weight of leaves, dry weight of leaves, number of cuttings per month, yield in kg/m^2. Characterization of genotypes were done for characters like vine colour, leaf outline, leaf lobe type, number of leaf lobes, shape of central lobes, mature leaf size, mature leaf colour and petiole length. The minimum and maximum observations with mean values are depicted in table 4.2

Table 4.1: Analysis of variance for different characters in water spinach genotypes cultivated under wall culture

Characters/source of variance	Mean Sum of Squares	
	Treatment	Error
d.f.	**17**	**54**
Vine length (cm)	223.97**	1.95
Vine weight (g)	113.73**	3.78
Foliage yield (Kg/m2)	0.40**	0.01
Number of cuttings per month	0.06ns	0.05
Internodal length(cm)	2.07**	0.39
Number of nodes/vine	0.65**	0.25
Leaf length (cm)	5.19**	0.18
Leaf width (cm)	2.67**	0.10
Petiole length (cm)	3.75**	0.13
Dry matter % of foliage	17.51**	0.69
Moisture % of foliage	18.80**	0.55
Fresh weight of leaves	88.65**	0.87
Dry weight of leaves	1.40**	0.26
Leaf: vine ratio	0.09**	0.01
**Significant at 1% level of significance *ns:- non significant at both 1% and 5% level of significance		

The ANOVA indicates that the genotypes have highly significant differences among them for all the characters except for number of cuttings per month which differs non-significantly both in 5% and 1% level of significance.

Table 4.2: Mean performances of the genotypes

S. No	Character	Minimum	Maximum	Average
1	Vine length (cm)	IGWS-7 (22.43)	IGWS-8 (45.89)	33.99
2	Vine weight (g)	IGWS-3 (10.36)	IGWS-2 (28.65)	18.51
3	Internodal length (cm)	IGWS-9 (4.89)	IGWS-1 (7.31)	5.95
4	Number of nodes per vine	IGWS-1 (2.00)	IGWS-9 (3.5)	2.65
5	Leaf length (cm)	IGWS-1 (5.15)	IGWS-2 (10.47)	6.52

6	Leaf width (cm)	IGWS-7 (2.24)	IGWS-2 (5.63)	3.27
7	Petiole length (cm)	IGWS-10 (4.19)	IGWS-2 (8.34)	5.39
8	Dry matter %	IGWS-25 (14.24)	IGWS-8 (21.79)	18.21
9	Moisture %	IGWS-8 (77.07)	IGWS-25 (85.74)	81.14
10	Fresh weight of leaves (g)	IGWS-10 (6.20)	IGWS-1 (25.78)	13.44
11	Dry weight of leaves (g)	IGWS-10 (3.23)	IGWS-2 (5.12)	4.06
12	Leaf: vine ratio	IGWS-3 (0.74)	IGWS-14 (1.20)	1.07
13	Number of cuttings per month	IGWS-3 (1.18)	IGWS-2 (1.75)	1.48
14	Yield (kg/m2)	IGWS-3 (0.17)	IGWS-2 (1.47)	0.64

4.2 Characterization of genotypes

The vine colour of genotypes varied from green to mostly purple. IGWS-2 was characterized as green vine colour, whereas IGWS-1, IGWS-5, IGWS-10, IGWS-14, IGWS-16, IGWS-18, IGWS-19, IGWS-
20 were characterized under mostly purple colour category. Green with many purple spots included genotypes IGWS-3, IGWS-4, IGWS-7, IGWS-8, IGWS-11, IGWS-15, IGWS-and IGWS-25, whereas, IGWS-6 and IGWS-9 have green with few purple spots vine colour. The leaf shapes varied from cordate to hastate. IGWS-1 has cordate leaf shape, whereas IGWS-2, IGWS-6, IGWS-11, IGWS-14, IGWS-15, IGWS-16, and IGWS-25 genotypes falls under triangular leaf shape category. Hastate leaf shape included IGWS-3, IGWS-4, IGWS-5, IGWS- 7, IGWS-8, IGWS-9, IGWS-10, IGWS-18, IGWS- 19, and IGWS-20. The leaf lobe type varied from no lateral lobes to slight lateral lobes type. IGWS-1, IGWS-2, IGWS-6 have no lateral lobes, whereas IGWS-3, IGWS-7, IGWS-9, IGWS-10, IGWS-14, IGWS-15, IGWS-16, IGWS-18, IGWS-19, IGWS- 20 and IGWS-25 have very slight leaf lobe type. The genotypes IGWS-4, IGWS-5, IGWS-8, and IGWS- 11 have slight leaf lobes. The number of leaf lobes among the planted genotypes varied from 1 to 9. IGWS-1 IGWS-2 and IGWS-6 have single leaf lobe. IGWS-3, IGWS-8 and IGWS-15 have 3 leaf lobes, whereas, IGWS-11 have 4 leaf lobes. 5 leaf lobes were found in IGWS-4, IGWS-5, IGWS-7, IGWS- 10, IGWS-14, IGWS-16, IGWS-18, IGWS-19, and IGWS-20. In IGWS-9, 6 leaf lobes were observed, whereas highest number of leaf lobes was recorded in IGWS-25, which has 9 leaf lobes. The shape of central leaf lobe was found to be under two categories, as, toothed and linear, based on general outline of central leaf lobe. The linear shape was found to have two categories in it depending upon its width, which were broad and narrow. IGWS-1, IGWS-2 and IGWS-6 were categorized under toothed shaped. IGWS-3, IGWS-4, IGWS-5, IGWS- 7, IGWS-8, IGWS-11, IGWS-14, IGWS-15, IGWS- 18, IGWS-19, IGWS-20 and IGWS-25 were under linear (broad) category, whereas, linear (narrow) central leaf lobe was observed in IGWS-9 and IGWS-10 only. Mature leaf colour ranged from completely green to green with purple edges. The genotypes, which have completely green leaf colour were IGWS-2, IGWS-5, IGWS-6, IGWS-8, IGWS-9, IGWS-14, IGWS-15, IGWS-16 and IGWS-25, whereas, IGWS-1, IGWS-3, IGWS-4, IGWS-7, IGWS-10, IGWS-11, IGWS-18, IGWS-19 and IGWS-20 have green with purple edges leaf colour.

4.3 Cost economics of water spinach genotypes cultivated under wall culture

The net profit per plot ranged from Rs -94.47 (IGWS-3) to Rs. 155.94 (IGWS-2). The minimum net profit was obtained from IGWS-3 (Rs. -94.47), whereas maximum net profit was obtained from IGWS-2 (Rs. 155.94), followed by IGWS-4 (Rs. 85.45) and IGWS-9 (Rs. 25.46). The gross profit ranged from Rs. 26.71 (IGWS-3) to Rs. 277.13 (IGWS-2). The minimum gross profit was obtained from IGWS-3 (Rs. 26.71), whereas maximum gross profit was obtained from IGWS-2 (Rs. 277.13), followed by IGWS-4 (Rs. 206.64) and IGWS-9 (Rs. 146.65).

Thus minimum income (both gross and net) was obtained from IGWS-3, whereas, the maximum income (both gross and net) was obtained from IGWS-2. Thus the genotype which proved to be best suited for wall culture was IGWS-2. However IGWS-4 and IGWS-9 can also be used for vertical farming. The benefit: cost ratio ranged between - 0.779 (IGWS-3) to 1.286 (IGWS-2). The genotype which has lowest benefit: cost ratio was IGWS-3 (- 0.779) whereas IGWS-2 proved to be best suited for vertical farming with a benefit: cost ratio of 1.286.

4.4 Organoleptic observations of water spinach genotypes cultivated under wall culture

The observations for organoleptic evaluations revealed that the genotypes which are excellent for consuming as raw green leafy salad were IGWS-1 (4.0), IGWS-2 (4.5), IGWS-7 (4.2), and IGWS-19 (4.2). The most preferred genotype was IGWS-2. However, some genotypes were also good in taste as green salad, these were IGWS-5 (3.8), IGWS-16 (3.8) and IGWS-25 (3.9). IGWS-6 and IGWS-14 have an after taste therefore, were considered as bad in taste for consuming as green leafy salads. The genotypes which tasted excellent as cooked bhanji were IGWS-1 (4.0), IGWS-2 (4.5), IGWS-7 (4.0), IGWS-16 (4.0), IGWS-19 (4.3) and IGWS-25 (4.0).

The most preferred genotype was IGWS-2. However, genotypes IGWS-5 (3.5), IGWS-15 (3.2), IGWS-18 (3.9) and IGWS-20 (3.8) were also considered as good in taste when cooked as bhanji. IGWS-14 was least preferred and rated 2.0. The genotype which was rated highest when cooked as pakora with gram flour was IGWS-3 with an overall rating of 3.5. The other genotypes which were rated as excellent were IGWS-10 (4.5), IGWS-11 (4.2), IGWS-14 (4.4), IGWS-18 (4.3) and IGWS-20 (4.3). The genotypes which were rated as good were IGWS-6 (3.8), IGWS-8 (3.9) and IGWS-15 (3.8). IGWS-1 and IGWS-25 were rated as average in taste with rating of 2.5. The overall ratings of the genotypes ranged between 2.76 (IGWS-9) to 4.0 (IGWS-2). The lowest rating was given to IGWS-9, however, highest rating was given to IGWS-2 (4.0), followed by IGWS-19 (3.76), IGWS-7 and IGWS-18 (3.73).

5. Summary and Conclusions

The maximum vine weight, longest leaf and petiole length, maximum dry weight of leaves, highest number of cuttings per month and maximum foliage yield was recorded in IGWS-2. The maximum vine length was recorded in IGWS-8, the longest internodal length was recorded in IGWS-1. IGWS-9 had maximum number of nodes per vine. IGWS-8 had maximum dry matter percent whereas; highest moisture percent was recorded in IGWS-25. The fresh weight of leaves was recorded maximum in IGWS-1 and highest leaf: vine ratio was recorded in IGWS-14.

Study on cost economics revealed that genotype IGWS-2 had maximum B: C ratio which implies that it is well suited for cultivation under wall culture. The organoleptic observations of the genotypes revealed that IGWS-2 is excellent as green leafy salad as well as cooked bhanji, however, for pakora IGWS-3 was excellent. The produce obtained from wall culture were healthy and free from liver fluke contamination which was recorded many times in Chhattisgarh due to cultivation of water spinach in water stagnant and swampy areas.

Based on these experimental findings, it may be concluded that wall culture is a great approach to obtain healthier and fresh produce without depending upon arable lands and skilled labours, especially for leafy vegetables like water spinach, also, IGWS-2 is best suited for wall culture cultivation. IGWS-2 had highest B: C ratio, have maximum yield attributing characteristics, attractive in appearance and also tastes excellent as leafy salad and cooked bhanji, therefore, IGWS-2 can be recommended for vertical farming (wall culture).

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