Int. J. Agriworld, Vol. 6[1] January 2025
©2020 SVPSS, India
Online ISSN: 2582-7537
Journal's URL:http://www.svpss.in/ijaw
DOI: https://doi.org/10.51470/IJAW.2025.06.01.36
Received 10.11.2024 Revised 20.12.2024 Accepted 16.01.2025
REVIEW ARTICLE **OPEN ACCESS**

Microgreens and their Potential Health Benefits

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Abstract
Microgreens are young, tender seedlings of vegetables or herbs, often harvested when they reach a height of 2 to 4 inches. They are widely appreciated for their ability to enhance the color, texture, and flavor of salads and various dishes. Unlike their mature counterparts, which can take 8 to 10 weeks to grow, microgreens are typically ready for harvest within just 7 to 21 days. These miniature greens are becoming increasingly popular as a specialty crop that can be easily grown at home or purchased from markets. They can be cultivated from a wide variety of seeds including those of vegetables, herbs, grains, and even certain wild species. Microgreens are drawing growing consumer interest not only for their vibrant appearance and intense flavors but also for their impressive nutritional profile. For instance, varieties such as broccoli, kale, and red cabbage are known to contain high levels of sulforaphane—a compound associated with anti-inflammatory and anti-cancer properties. Their concentrated flavors mean that only small amounts are needed to enhance the taste of meals. These greens can be conveniently grown indoors, even on a sunny windowsill, making them a favorite among urban gardeners. However, because of their delicate structure and high moisture content, they should be consumed raw and handled gently. Cooking is generally discouraged as it may degrade their nutrients. It's advisable to select brightly colored microgreens, as they often contain higher levels of beneficial compounds. As both a visually appealing garnish and a powerhouse of nutrition, microgreens are an excellent addition to a balanced diet. Their ease of cultivation with minimal resources has contributed to their rising popularity in home gardens across India.

Keywords: Microgreens, nutritional value, antioxidants, vitamins, salads.

Introduction

As urban populations continue to surge globally, there is an increasing need for food systems that are not only nutritious and accessible but also environmentally sustainable. Urban agriculture, particularly controlled environment agriculture (CEA) systems such as vertical farming, hydroponics, aquaponics, and greenhouse cultivation, has garnered significant interest from both private enterprises and government bodies (Benke and Tomkins, 2017). Despite its promising potential, CEA is still in its developmental stages and currently suited to a limited range of crops. Among the most widely adopted crops in controlled environments are microgreens. These are ideally suited for hydroponic systems—the most commonly used method in indoor farming—as well as soil-based cultivation. The term "microgreens" refers to the young, edible seedlings of vegetables, herbs, or grains, including native and wild species. These tiny plants represent an intermediate growth stage between sprouts and baby greens. Unlike sprouts, which are harvested before leaves develop, microgreens are typically grown until their first true leaves appear, usually within 7 to 21 days after germination. While similar to baby greens in that their stems and leaves are consumed, microgreens are harvested at a much younger stage and are significantly smaller in size. One unique advantage is that they can be sold as live plants, allowing consumers to harvest them fresh at home, enhancing both their shelf life and nutritional quality. Their adaptability allows them to be cultivated in diverse settings—from outdoor gardens and greenhouses to indoor spaces like kitchen counters or sunny windowsills—making them a versatile and convenient option for modern urban farming.

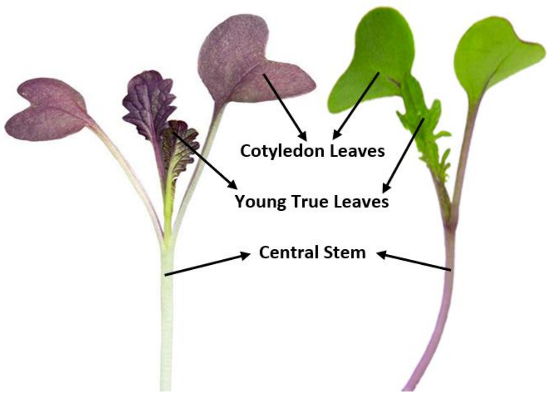

Figure1: Microgreens and their important components (Khan *et al.*, 2024)

Since their debut in Californian restaurants during the 1980s, microgreens have experienced a surge in popularity, particularly in the last decade, due to their fresh flavor and exceptional nutritional properties (Lenzi *et al.*, 2019). Owing to their concentrated nutrient profile and more pronounced flavor, they are often regarded as a superior alternative to traditional sprouts (Puccinelli *et al.*, 2019). Microgreens are known to contain greater concentrations of vitamins, minerals, and phytochemicals compared to their fully mature counterparts (Xiao *et al.*, 2012; Yadav *et al.*, 2019). As such, incorporating them into daily meals can enhance the overall nutritional value of the diet and support improved health outcomes. Despite their advantages, cultivating and distributing microgreens presents certain challenges. Their delicate structure and short shelf life make post-harvest handling and storage difficult (Puccinelli *et al.*, 2019). To address these issues, researchers have explored various pre- and post-harvest interventions aimed at enhancing both shelf life and nutritional content (Allegretta *et al.*, 2019). As microgreens are still considered a relatively novel and niche crop, scientific research into their health benefits and nutritional qualities is still emerging. Microgreens can be cultivated from a wide variety of plant families, including Brassicaceae (e.g., broccoli, cauliflower, cabbage, radish, arugula, watercress), Asteraceae (e.g., lettuce, endive, chicory, radicchio), Apiaceae (e.g., dill, carrot, fennel, celery), Amaryllidaceae (e.g., garlic, onion, leek), Amaranthaceae (e.g., amaranth, quinoa, Swiss chard, beet, spinach), and Cucurbitaceae (e.g., melon, cucumber, squash). Additionally, cereal grains such as wheat, barley, corn, oats, and rice, along with legumes like lentils, chickpeas, and beans, are also sometimes used to grow microgreens (Renna *et al.*, 2017). The flavor of microgreens varies widely by variety, ranging from mild or neutral to spicy, tangy, or slightly bitter, but is generally considered to be more intense and concentrated than that of mature vegetables.

Figure2: Fenugreek microgreens grown in the laboratory

Nutrient contents

Microgreens are renowned for their rich nutritional profile, often containing significantly higher levels of essential nutrients compared to their mature counterparts. In fact, nutrient concentrations in microgreens can range from 4 to 40 times greater than those found in fully grown plants. For instance, red cabbage microgreens have been reported to contain up to 40 times more vitamin E and six times more vitamin C than mature red cabbage (Pratap *et al.*, 2023). Similarly, certain species of microgreens (cilantro, mustard, coriander) possess triple the amount of beta-carotene compared to mature cilantro (Anonymous, 2023; das and Dhar, 2023). Research indicates that microgreens are also abundant in antioxidants. Species from the Brassicaceae family, such as broccoli, are particularly rich in vitamin E—a potent phenolic antioxidant. Likewise, members of the Asteraceae family, including lettuce and chicory, tend to have high levels of vitamin A, primarily in the form of carotenoids. Scientists have paid special attention to antioxidants like vitamin C, phytochemicals (including carotenoids and phenolic compounds), and trace minerals such as copper (Cu), zinc (Zn), and selenium (Se), all of which help neutralize free radicals and mitigate oxidative stress.

Numerous studies have compared the antioxidant capacity and nutrient content of microgreens with their mature equivalents (Pinto *et al.*, 2015; Choe *et al.,* 2018). Many microgreens were found to be richer in various antioxidants (Yadav *et al.,* 2019; Di Bella *et al.,* 2020). For example, vitamin C content in microgreens of jute (*Corchoris olitorius* L.) and cucumber (*Cucumis sativus* L.) was 25 and 34 mg/100 g fresh weight (FW), respectively—higher than their mature forms, which contained 17.45 and 10 mg/100 g FW (Yadav *et al.,* 2019). Similarly, the microgreen stage of traditional Sicilian broccoli contained 7.5 mg/g of vitamin C, compared to 6.1 mg/g in its baby green stage (Di Bella *et al.,* 2020).

Other studies also reported impressive increases in vitamin C content in the microgreens of fenugreek (*Trigonella foenum-graecum* L.), spinach (*Spinacia oleracea* L.), and roselle (*Hibiscus sabdariffa* L.), with levels exceeding their mature stages by 120%, 127%, and 119%, respectively (de la Fuente *et al.,* 2019). The vitamin C concentration in ten commercial microgreen varieties ranged between 29.9 and 123.2 mg/100 g FW, comparable to citrus fruits—well-known sources of this nutrient (Ghoora *et al.,* 2020). Another study reported vitamin C levels ranging from 20.4 to 147.0 mg/100 g FW across 25 different microgreen types, with many showing greater concentrations than mature plants (Xiao *et al.,* 2012). Since microgreens are typically consumed raw, much of their vitamin C content is preserved, avoiding losses associated with cooking (Yadav *et al.,* 2029; Khosravi and Asadollahzadeh, 2014).

Trace minerals such as Cu, Zn, and Se are vital for the human body, functioning as cofactors in antioxidant enzymes like superoxide dismutase. These minerals are thus categorized as antioxidant minerals (Lee *et al.,* 2017). A deficiency in these nutrients may impair antioxidant enzyme activity (Wołonciej *et al.,* 2016). A study on nine summer leafy greens revealed that their microgreen forms contained substantially higher Zn levels (4.76 to 29.12 mg/kg FW) compared to their mature forms (1.23 to 5.50 mg/kg FW) (Yadav et al., 2019). Similarly, microgreens of bottle gourd and water spinach had higher copper levels than their adult stages. Kale microgreens also exhibited greater Zn and Cu concentrations than their mature counterparts (Harris, 1992). Comparative analysis of mineral profiles in legumes such as *Trifolium pratense*, *T. medium, Medicago sativa, M. lupulina, Onobrychis viciifolia*, *Astragalus glycyphyllos*, and *A. cicer* revealed that microgreens had 0.6 to 3.2 times more Zn than seeds and sprouted seeds (Waterland *et al.*, 2017; Butkutė *et al.,* 2018).

How to grow Microgreens?

Microgreens are simple to cultivate on a small scale and can grow well indoors with access to natural light. If you're interested in starting your own batch, follow these easy steps:

a. Evenly spread the seeds over about an inch of moist potting mix in a shallow container or tray.
b. Gently mist the potting mix with fine drop hand sprayer and cover the container for a blackout period of 2-3 days
c. After the sprouting of seeds place the container in a well-lit spot out, such as near a sunny window or under a grow light.
d. Keep the soil consistently moist by misting it daily until the microgreens are ready.

Typically, microgreens are ready to be harvested within 2 to 3 weeks. To harvest, snip the stems just above the soil surface using clean scissors, and make sure to rinse the greens thoroughly before consuming.

Types of Microgreens

There are countless herbs and vegetables that can be cultivated as microgreens—over 40 varieties are commonly grown for their unique flavors, visual appeal, and nutritional benefits. Below are eight beginner-friendly microgreens perfect for a home garden:

1. Sunflower Microgreens

Sunflower microgreens offer a rich, nutty flavor and are incredibly easy to grow (Samuoliene *et al.,* 2013). They're ready to harvest in about two weeks. Use small containers like repurposed milk cartons or salad boxes and fill them with a moist seed-starting mix. These greens need ample light and airflow, so uncover the container once the seeds begin sprouting. Great in salads, soups, sandwiches, or even smoothies, sunflower microgreens are rich in calcium, iron, and vitamins A, B-complex, C, D, and E. They're also easily digestible (Kyriacou *et al.,* 2016).

2. *Radish Microgreens*

These spicy microgreens can be harvested in just 10 days and grow well when seeds are sown densely on moist soil. Radish microgreens add crunch and a peppery zing to meals. Nutritionally, they're packed with manganese, vitamin B3 (niacin), B6, folate, and vitamin C (Xiao *et al.,* 2012).

3. Pak Choi Microgreens

Pak choi can be grown in soil or hydroponically. During the first three days, they require darkness to sprout properly. Harvest by slicing the stems cleanly with a sharp knife. These tender greens have a subtle flavor that complements soups and salads. They're high in vitamins C, K, and E, beta-carotene, and iron. The presence of glucosinolates gives them potential anti-cancer properties (Tocmo *et al.,* 2022).

4. Broccoli Microgreens

Broccoli microgreens are among the most nutritious options and can be harvested in just 6–10 days (Fahey et al., 1997; Xiao *et al.,* 2012). Plant the seeds in shallow trays with light, moist soil and harvest once they reach 2–3 inches in height. They bring an earthy taste and crunchy texture to dishes and contain higher nutrient levels than mature broccoli. These microgreens are rich in vitamins A and C, iron, calcium, fiber, and boast impressive 35% protein content (Xiao *et al.,* 2012; Choe *et al.,* 2020).

5. Cabbage Microgreens

Cabbage microgreens grow well in shallow containers. Sow the seeds densely and maintain a warm, moist environment for the first few days. Once sprouted, ensure good air circulation and drainage. Harvest when the leaves open fully. Use them in salads, sandwiches, and garnishes. They're an excellent source of vitamin C, E, beta-carotene, and antioxidants (Xiao *et al.,* 2012).

6. Spinach Microgreens

These greens are easy to grow using common household supplies. Use shallow containers and keep the seeds in the dark for 2–3 days to help germination. Afterward, place them in a sunny window and water regularly without over-saturating the soil. Spinach microgreens provide a fresh burst of color and flavor to soups, salads, and wraps. They're loaded with nutrients like vitamins A, C, and K1, folate, iron, and calcium. In fact, they contain up to 40 times the nutrients of mature spinach (Xiao *et al.,* 2012).

7. Beetroot Microgreens

Beet microgreens bring vibrant pinks and reds to your tray, making them as decorative as they are nutritious. Although they take a bit longer to grow than others, they're worth the wait. Ensure proper drainage as their roots don't tolerate waterlogging.

With a naturally sweet, earthy flavor, beet microgreens enhance salads, pasta, soups, and sandwiches. They are rich in vitamins A, B, C, E, and K, iron, calcium, protein, magnesium, potassium, and copper (Kou *et al.,* 2013).

8. Corn Microgreens

These sweet-tasting microgreens develop quickly. Soak the seeds for at least 8 hours before planting, and harvest them by cutting about half an inch above the soil.

When grown in low light, they produce golden-yellow shoots with an intensely sweet flavor. In full sunlight, they turn dark green with a more earthy taste. Use them wherever a sweet element is needed. Corn microgreens support immune health, bone strength, and blood pressure regulation. They contain vitamins A, B, C, and E, along with calcium, magnesium, and antioxidants (Ghoora *et al.,* 2020).

Factors that affect Microgreen Yield and Quality

Microgreens can be cultivated either in open environments or under controlled conditions such as greenhouses with artificial lighting. They are typically grown using soil-less systems that employ organic or inorganic substrates or hydroponic media such as peat moss, vermiculite, or perlite. Several critical factors influence the fresh biomass and nutritional quality of microgreens, including plant type, seed density, growth substrate, light exposure, pre-sowing treatments, and nutrient availability.

Effect of Sowing Density on Microgreen Productivity and Quality

Achieving the right seeding density is vital for successful microgreen cultivation. Research indicates that optimal seeding density contributes significantly to maximizing yield and maintaining product quality (Bayineni & Kavana, 2022; Bhaswant *et al.,* 2023). While higher seed densities may improve total yield and offset the high cost of seeds, they also increase the risk of fungal diseases, which can reduce product quality and overall profitability. Due to variability in seed size even within a single species or cultivar, determining a universal seeding rate is difficult. Seed lots may differ depending on how they were produced (Bulgari *et al.,* 2017), requiring growers to adjust seeding densities with every new batch of seeds and based on specific growing conditions (Kyriacou *et al.,* 2016).

Crop-specific seeding rates are typically calculated based on seed weight, germination potential, and desired shoot density. For example, large-seeded crops like peas, chickpeas, and sunflower are best sown at around 1 seed/cm², while smaller seeds like arugula or mustard may need up to 4 seeds/cm² (Di Gioia & Santamaria, 2015). Murphy and Pill (2010) found that increasing the sowing rate in crops like arugula and beet improved yield per unit area but reduced the average shoot weight. Excessive density can also lead to spindly growth and poor air movement, promoting disease development. A comprehensive overview of different cultivation parameters including seed rate along with harvest timelines, flavor, and coloration for various microgreen species is presented in Table 1.

Effect of Growing Medium on Yield and Quality

The choice of growing substrate significantly affects both production cost and the physical quality of microgreens. It also influences nitrate accumulation in the produce, which directly impacts its safety and marketability (Bulgari *et al.,* 2021). An ideal growing medium should be cost-effective, locally sourced, renewable, and possess suitable water retention and aeration capacity (Di Gioia *et al.,* 2015). Optimal media should have 55–70% water holding capacity and 20–30% air space by volume. A neutral pH and loose texture are also desirable for microgreen cultivation (Lau *et al.,* 2019).

Peat-based substrates remain widely used due to their favorable properties (Muchjajib *et al.,* 2015). Coconut coir is a sustainable alternative but often varies in quality and may have high salt levels or microbial contamination (Prasad, 1997). Synthetic media like rockwool and PET mats are also used but pose environmental disposal challenges (Kyriacou *et al.,* 2016). More sustainable options include biodegradable, natural fiber-based substrates such as jute (burlap), kenaf, hemp, cotton, and cellulose pulp (Di Gioia *et al.,* 2019). These can be blended to enhance physical properties and may be enriched with nutrients or beneficial microbes to enhance plant growth and suppress pathogens.

Impact of Light on Microgreen Growth and Composition

Light is a critical environmental factor affecting microgreen growth, photosynthetic efficiency, morphological development, and nutritional composition. Parameters such as light intensity, duration (photoperiod), and quality (wavelength spectrum) directly influence plant development (Liu *et al.,* 2022; Craver *et al.,* 2017). Light intensity between 100–300 μmol m^{-2} s^{-1} is commonly used for microgreen production. Photoperiods of 12 to 16 hours are standard in controlled-environment agriculture and significantly affect both biomass accumulation and secondary metabolite production (Hernández-Adasme *et al.,* 2023). LED lighting has become a preferred choice due to its energy efficiency and ability to tailor spectral outputs to crop-specific needs (Morrow, 2008; Zhang *et al.,* 2020). Different species respond uniquely to various lighting conditions. Red and blue wavelengths are known to promote photosynthesis and morphology, while far-red and green light can fine-tune growth responses. Thus, precise control over lighting regimes can be used to enhance both productivity and phytochemical richness in microgreens.

Role of Nutrition in Enhancing Microgreen Yield and Quality

Although microgreens can grow without external nutrients, their nutritional profile can be significantly improved through the application of macro- and micronutrients. Supplementing nutrient solutions—either through fertilization or fertigation—can improve both biomass and bioactive compound accumulation (Petropoulos *et al.,* 2021). With the transition to soilless growing systems (e.g., coconut fiber, perlite, vermiculite), nutrient management becomes even more critical (Riggio; Mohammad *et al.,* 2022). Studies comparing soil-based and hydroponic cultivation methods have found that hydroponics often lead to better nutrient uptake and improved functional compound concentration (Mohanty *et al.,* 2021). Adjusting the nutrient composition can enhance specific compounds like glucosinolates in Brassica microgreens (Yang *et al.,* 2015), boosting their health-promoting properties.

Conclusion

Microgreens offer a nutrient-dense, flavorful, and visually appealing addition to the modern diet. They are simple to grow at home and can be produced sustainably with minimal resources. For Indian agriculture and food sectors, microgreens represent a promising new niche due to their high market potential and adaptability. With eco-friendly practices—such as using organic seeds, compostable media, and renewable energy—microgreens can be grown in a way that's both nutritious and sustainable, offering a smart alternative to conventional, resource-intensive farming systems.

Table1: Seed rate, soaking, blackout and germination periods of different microgreen species

S. No.	Plant Species	Seed rate (g/1020 tray)	Soaking Period (hours)	Black out Period (days)	Germination time (days)	Ideal Harvest time (days)	Taste/ Flavor	Colour
1.	**Alfalfa**	25	8-12	5-6	2-5	10	Mild, slightly nutty flavor	Vibrant green
2.	**Anise**	15-20	No	5-7	2-5	20	Essential, spicy	Green
3.	**Amaranth red**	15	No	5-6	2-3	12	Mild, earthy	Red
4.	**Argula**	12	No	4-6	3	10	Peppery	Green color
5.	**Basil**	10	No[+]	4-7	3-4	22	Intense	[+]mucilaginous
6.	**Beet root**	20-30	4-8[+]	4-5	3-4	10	Earthy	[+]in cold water
7.	**Borage**	36	No	4-5	2-3	14-20	Cucumber taste	Green leaves/white stem
8.	**Broccoli**	15-20	No	2-3	2-3	10	Mild cabbage	Green color
9.	**Brussell sprout**	15-20	No	2-3	1-2	10	Mild brussels sprout	Dark green
10.	**Buckwheat**	100	4-8	3-5	1-2	10	Mild, tart / tangy	pale green color
11.	**Cabbage[1]**	15-20	No	2-3	1-2	10	Mild cabbage	Rich-green /purple veins
12.	**Carrot**	15-20	No	2-3	5-7	16	Mild sweet and slightly earthy	Green leaves/white stem
13.	**Cauliflower**	15-20	No	2-3	1-2	10	mild cauliflower	Green with violet stem
14.	**Celery**	15-20	No	4-5	12-15	15-35	Sharp celery	Light green
15.	**Chard**	20-30	4-8[4]	4-5	3-4	10	Chard / spinach	[4]In cold water
16.	**Chia**	10-15	No	3-5	2-3	10	Earthy	Green leaves
17.	**Chickpeas**	300	8-12	2-4	6	15-17	Mild, nutty flavor similar to chickpeas	Green
18.	**Cilantro[6]**	30-40	2-4	7	7-14	21-28	Intense cilantro / coriander	[6]Chinese parsley
19.	**Clover**	15-20	No	2-3	1-2	10	Mild, fresh, slightly sweet	Green
20.	**Collard Greens[7]**	150-20	No	2-3	2-3	10	Fresh, intense collard flavor	[7]Vates; Color – Dark reen
21.	**Corn (Popcorn)**	225-275	2-6[8]	3-4	1-2	6	Crunchy, fresh and very sweet	[8]In cold water
22.	**Coriander**	30-40	6-10[15]	5-6	7-10	21-28	Citrusy and slightly peppery	[15]24h in some cv.
23.	**Cress**	20	No	4-5	3-5	10	Intense peppery	Green
24.	**Dil**	15-20	4[11]	4-5	4-5	15	Mild dill, zesty	[11]In cold water
25.	**Endive**	15-20	No	3-5	2-3	10	Mild, contrasting bitter	Green/ red
26.	**Fennel**	20-30	No	3-4	2-3	16+	Mild, anise flavor	Green
27.	**Fenugreek**	50	4-7	3	3-5	9	Crunchy, mild flavor	Green
28.	**Flax (Alsi)**	15-20	No	2-4	2-3	10	Nutty taste with sharp flavour	Green leaves/white stem
29.	**Kale**	15-20	No	2-3	2-3	10	Fresh kale	Dark green
30.	**Kohlrabi**	15-20	No	2-3	2-3	10	Mild cabbage	Green
31.	**Large leaf sorrel[10]**	3	No	3-5	1-2	12	Bright, lemony flavor	[10]Red veined sorrel
32.	**Leeks[5]**	40-50	No	4	1-2	21	Onion	[5]Chive or green onion
33.	**Lettuce**	15-20	No	2-3	2-3	10	Concentrated lettuce	Green / red
34.	**Marigold**	3-5	No	4-5	4-5	12	Citrusy greens flavour	Green
35.	**Mung bean**	215	12	3-4	2-3	9	Neutral	Green leaves
36.	**Mustard**	10-15	No	3-5	2-3	10	Spicy mustard	Green
37.	**Parsley**	15-20	No	4-5	6-7	16+	Mild parsley	Green
38.	**Pea**	200-275	6-12[9]	3-5	2-3	10	Mildly sweet, fresh	[9]Cold water
39.	**Radish**	30-35	No	2-3	1-2	10	Strong radish	Green
40.	**Red Komatsuns**	10-15	No	3-5	2-3	10	Fresh with very mild spice	Green
41.	**Sunflower**	150	6-12	2-3	2-3	10	Crunchy, nutty, fresh	Green
42.	**Turnip**	24	No	2-3	2-3	7-9	Zesty, Slightly spicy flavor	Green leaves
43.	**Wheat grass**	450	4-8	2	2-3	10	Fresh green	Green

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CITATION OF THIS ARTICLE

Khan, F.A., Hussain, S., Waheed, W., Dar, Z.M., Amir, M., Moinuddin, Khan, F. and Narayan, S. (2025). Microgreens and their Potential Health Benefits, *Int. J. Agriworld*, 6 [1]: 36-44.