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AEROBIC RICE: MITIGATING WATER STRESS

Article Id: AL201923

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One of the most vital inputs in agriculture is water which is providing a significant contribution in food grain production and productivity. India has 2.4 per cent of land mass and 4.2 per cent fresh water resources of the World, but it supports 17.0 per cent of the human population and 16.3 per cent of livestock population of the world. The per capita per year availability of water in India was 5300 m^3 in the year 1950 which is projected further to dwindle to 1465 and 1191 m^3 by the year 2025 and 2050, respectively. Water supply considers a limiting factor for crop production and food security under the current and future conditions.Notably, above 98% of the irrigated lands are under the coverage of surface irrigation where more than 50% of water is considered as wastages. Under such circumstances water should be applied and used judiciously and economically to mitigate the increasing food demand. Keeping that water scarce situation in mind, adoption of Micro irrigation systems (e.g. drip and microsprinkler) can ensure higher water use efficiency, besides obtaining higher yields with considerable saving in irrigation water in the Indian agriculture.

Origin and history of aerobic rice cultivation

International Rice Research Institute (IRRI) developed the aerobic rice technology to manage the water crisis in tropical agriculture. In aerobic rice systems, the crop is grown in non-puddled, non-flooded fields and rice is grown like an upland crop (unsaturated condition). Adequate inputs and supplementary irrigation is provided when rainfall is insufficient. This brandnew concept of aerobic rice may be an alternate strategy, in combination with the characteristics of rice varieties adopted in upland with less water requirement and irrigated varieties with high response to inputs. In China, it has been observed that the water use for aerobic rice production was 55–56% lower than the flooded rice with 1.6–1.9 times higher water productivity. It proves that aerobic rice may be a viable alternative for cultivating lowland rice in spite of the fact that shortage of water is prevailing in that particular area.

Upland and Aerobic rice

In most cases upland rice is grown in rain fed and naturally well-drained soils that are usually on sloping land with erosionproblems, drought-prone, and poor in physical and chemical properties. Upland rice varieties are low-yielding butdrought- and low-fertility-tolerant, thus giving low but stable yields under the adverse environmental conditions ofuplands. However, high levels of inputs of fertilizer and supplemental irrigation to upland rice will lead to lodgingand thus reduce yield.Aerobic rice is targeted at more favourable environments where land is flat or terraced, and soil can befrequently brought to water field capacity by rainfall or supplemental irrigation, or where land is sloping butfrequent rainfall can keep soils moist throughout the growing season. Aerobic rice can be replacement oflowland rice wherever available water is insufficient for lowland rice but sufficient for aerobic rice. Both aerobic and upland rice are adapted to aerobic soil conditions, but aerobic rice varieties are more input-responsive and higher yielding than traditional upland ones.

Why aerobic rice

With an aim to increase crop water use efficiency aerobic rice is definitely an emerging cultivation system. Rice is water loving crop which mostly love submergence condition. For fulfilling the demand of irrigated rice cultivation approx...2000 litre of water is needed for producing 1 kg of rice which results is very low water use efficiency in irrigated rice cultivation. By reducing water use during land preparation and limiting seepage, percolation, and evaporation, aerobic rice had about 51% lower total water use and 32-88% higher water productivity, expressed as gram of grain per kilogram of water, than flooded rice. The labour use is also saved in aerobic rice because more labour is required for land preparation such as puddling, transplanting, and irrigation activities in flooded rice.Along with high water demand, the traditional system of transplanted rice production in puddled soil on long run leads to destruction of soil aggregates and reduction in macro pore volumes, and to an outsized increase in micro pore space which subsequently reduce the yields of post rice crops. Aerobic rice varieties produce yield as much as traditional irrigated puddled rice varieties.Yields were on par with irrigated puddled rice with an average of 5.5-6.0 t/ha with 60 percent less water use.Aerobic rice production system eliminates continuous seepage and percolation losses, greatly reduces evaporation as no standing water is present at any time during the cropping season, and effectively uses the rainfall and thus helps in enhancing water productivity, concomitant loss of soil sediments, silt and fertility from the soil. A comparison of water requirement of lowland flooded rice and aerobic rice system clearly shows that aerobic rice system can save about 45 per cent of water. Water saving in the aerobic rice system compared with the conventionally irrigated lowland rice results mainly from (1) no water losses during land preparation, (2) less percolation and seepage due to the elimination of the pressure head of the ponded water layer normally maintained in an irrigated field, and (3) less evaporation.

Table 1. Water Input (I=irrigation, R=Rainfall) and rice yield under different production environment

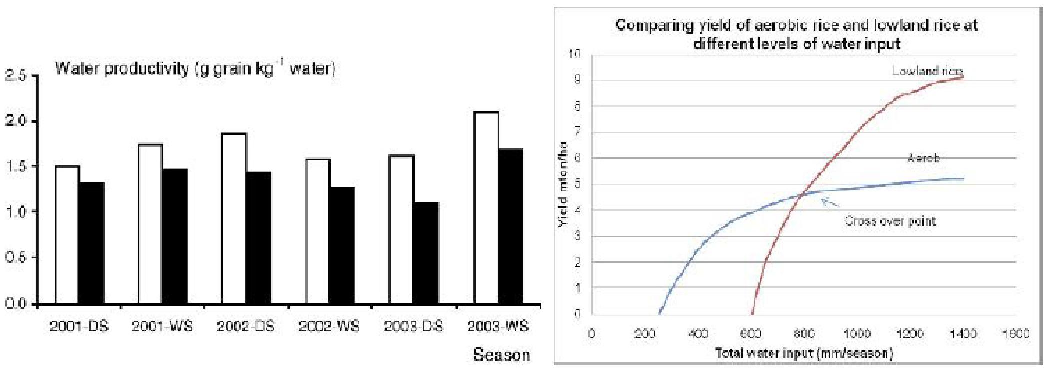
Year	Variety	Water Input I+R(mm)	Yield(t/ha)	Water productivity(kg/m3)
2001	Aerobic	1350	5.4-6.8	0.45
2002	Aerobic	1250	4.6-5.3	0.40
2007	Lowland	1200	6.0	0.50
2001	Aerobic	470-650	2.5-5.7	0.73
2002	Aerobic	550-900	2.9-5.7	0.59
2003	Aerobic	688	3.6-4.5	0.59
2003	Aerobic	600-700	5.0-6.0	0.85
2002	Aerobic	566	5.5	0.97
2007	Low Land	560	3.15	0.57

(Bouman*et al*., 2004)

Table 2. Water use of hypothetical aerobic and lowland rice on different soils

Water flow process	Aerobic Rice (mm)		Lowland Rice (mm)		
Lowland Soil SP rate	-	-	1 mm d-1	5 mm d-1	15 mm d-1
Irrigation Efficiency	85%	60%	-	-	-
Evaporation	100	100	200	200	200
Transpiration	400	400	400	400	400
Seepage and percolation	-	-	100	500	1500
Irrigation inefficiency loss	90	335	-	-	-
Total	590	835	700	1100	2100

(Bouman*et al*., 2004)



DS: dry season; WS: wet season (Bouman *et al*., 2005)

Figure 1. Yield of aerobic rice and lowland rice at different levels of water regimes

Some problems

Among rice ecosystems, therefore, the greatest weed pressure and competition occurs in upland and aerobic rice, and the least in transplanted irrigated and rainfed lowland rice.In conventional transplanted system, weeds are suppressed by standing water and by transplanted rice seedlings, which have a head start over germinating weed seedlings. On the other hand, aerobic soil dry-tillage and alternate wetting and drying conditions are conducive for germination and growth of weeds causing grain yield loss of 50 to 91%. Thus, it appears that weed is the major constraint to aerobic rice production and therefore, success of this technology mostly depends on effective weed management.In spite of these limitations, aerobic rice varieties have the ability to maintain rapid growth in soils with moisture content at or below field capacity, and can produce yields of 4-6 t/ha with a moderate application of fertilizers under such soil water conditions.

Carbon footprint

According to reports from several researches it has been observed that certain pests and diseases don't breed in aerobic conditions, therefore, use of chemicals is also reduced. A lot of aerobic rice varieties have been released in India and abroad.Paddy fields today are known to be one of the biggest agricultural anthropogenic sources of greenhouse gases (nitrous oxide and methane, in particular)."Aerobic rice severely reduces these gases by eliminating standing water, and thus, as a nation, we can reduce our carbon footprint and accrue carbon credits," Agrawal added.All this is possible without any compromise in grain yield. Mixed cropping and crop rotation practices are possible. Soil health improves since continuous mono-culture is curtailed.

Management of aerobic rice

As we know that dry direct seeding is the usual establishment method in rice cultivation. But in case of aerobic rice cultivation conservation agriculture such as mulching and minimum tillage can also be used. Several water saving technologies such as flash-flooding, furrow irrigation, drip and sprinkler irrigation can be used. But here mostly micro sprinkler irrigation was talked about aerobic rice cultivation system for mitigating water stress. In case of flooded rice, just to bring the water to the root zone up to field capacity flooding of the soil is done. Although it has been discussed that certain pests and diseases don't grow in case of aerobic rice but some soil borne pathogens such as nematodes, fungi are known to occur more in aerobic rice than in flooded rice. This incidence of infestation is more in tropical regions to curb the problem aerobic rice cultivation with a crop rotation of upland flooded rice cultivation is recommended.

Conclusion

Aerobic rice technology is a better scope for future climate change under drought situation aiding lesser greenhouse gas (GHG) emission. But selection of varieties with desired physiological attributes results in better performance. Proper care & cultural practices must be there for a weed free environment which is a great threat to aerobic rice cultivation compared to upland rice cultivation. Yield penalty and yield stability has to be considered for adoption in the farmers for aerobic rice culture.

Future scope

Drought tolerant varieties along with high yielding characters are suitable for aerobic cultivation. Stay green mutant plants on aerobic environment must be developed for future findings and research. The signalling mechanism of aerobic rice that reveal molecular mechanism involved under aerobic environment should be analysed.

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CATTLE BASED INTEGRATED FARMING SYSTEM AND IMPROVING INCOME THROUGH IT

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Integration is a *Latin* term meaning '*whole'* (entire part). Naturally, farmers rear all types of livestock and poultry in smallholdings with agricultural components of horticulture (vegetables and fruits), plantation, agroforestry (trees), sericulture (silk) either alone or in combination depending upon the landholding capacity of the farmers and other available resources. Integration is the concept where animals are reared on agricultural waste. Animals are used for ploughing and their dung is used as fertilizers/fuel i.e., the output of one unit is used as input of another unit. In the view of problems of insufficient monsoon rains, labour problem and insufficient price for the produced commodities, the concept of the Integrated Farming System (IFS) is gaining interest in the farmer's field level.

Advantages of Integrated Farming System

1. Yield and income per unit area per unit time will become improved.
2. Recycling of waste products can be donewith full efficiency.
3. The production level of milk, egg, meat, grains and crops will be increased.
4. Labour and land area can be efficiently utilized

5. Nutrient recycling can be done
6. Nutritional security to all the components of IFS can be achieved
7. Biogas and agro forestry enterprise inclusion in IFS can resolve the problem of the energy crisis
8. Soil erosion can be prevented
9. Regular employment generation and regular income to the farmers is possible
10. Regular and sufficient flow of input and output of one unit to another unit.

Components of IFS

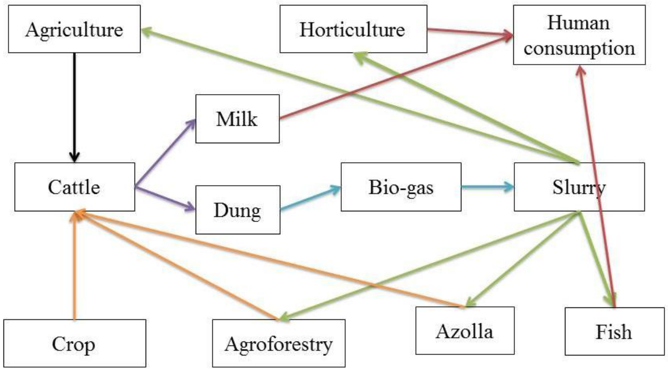
- Agriculture: Rice, Wheat, Maize, Sorghum, Millets
- Horticulture:
    - *Fruit crops:* Banana, Mango, Guava, Papaya, Apple
    - *Floriculture:* Flowers
- Fish: Marine water
- Animal Husbandry: All domestic animals (milk, meat, both)
- Agroforestry: Trees- timber

Sub-components

- Mushroom
- Beekeeping
- Azolla
- Berseem
- Sericulture
- Vermicompost

Types of livestock-based farming system

1. Cattle + Crop + Backyard Poultry
2. Agriculture + Cattle + Fish + Biogas
3. Agriculture + Cattle + Horticulture + Fish + Biogas
4. Agriculture + Cattle + Agroforestry + Fish + Biogas
5. Agriculture + cattle + Fish + Duck (living scavengers) + Biogas.



Agriculture

It includes fodder and crop by-products (after harvesting rice, wheat, maize, sorghum, Bajra). The fodder crop cultivated for cattle includes fodder maize, Napier grass. Minimum of two crops can be planted per year that includes Kharif crop (rice) and Rabicrop (wheat) and in between two crops, one additional crop *summer moong*can be cultivated that will increase the soil fertility. Farmyard manure/slurry(biogas by-product) can be used as a natural fertilizer to improvesoil fertility and increase production per unit area.

Cattle


Livestock Enterprise

Indigenous or crossbred animals can be used and the number of an animaldepends on land availability for the cultivation of fodder, by keeping in mind that one adult cattle consume 30-35 kg green fodder and about 4 kg busa per day. Minimum of 2 animals can be kept for the betterment and in one acre of land 2-3 animals be reared. Milk produced is sold to retailers/consumers directly or to the cooperatives. Dung, left overfeed, urine is recycled and can be used efficiently.

Horticulture

Horticulture includes *fruit crops* like mango, guava, banana, papaya and*vegetables*like brinjal, tomato, green chili, ladyfinger. The slurry or FYM from the biogas can be used as fertilizer for those plants. The harvested vegetables and fruits from the plants may be consumed by the farmers as organicor can be sold out to consumers.

Fish

Slurry by-products and droppings of poultry can be used as feed for fish. Major Six varieties of fish are being reared under Indian conditions which include Catla, Rohu, Mrigal, Common carp, Indian carp and Silver carp. For site selection of pond construction, water retention capacity of soil and soil fertilityshould be more. Ensure that water is available throughout the year. The minimum depth of the pond should be 3.8m and water should be upto 3m.

Types of fish	Percentage inclusion in the pond	
Catla	40	10
Rohu	30	10
Mrigal	30	10
Common carp		25
Grass carp		20
Silver carp		25

Goose cum Fish

Fish Pond

Biogas


Bio-Gas plant

A biogas plant is based on a number of animals. For 2-3 animals in a farm, 2m^3 size of a biogas plant to be considered. Dung will be used for biogas production and the remaining slurry will be used as farmyard manure for fish cultivation, agriculture and horticulture. Biogas plant to be maintained underanaerobic condition.

Plant size (m^3)	Minimum no. of animal
2	3
3	4
4	6
6	10

Azolla

It can be used as an alternative to green fodder and concentrate with reducing the feed inclusion cost. There are 6 varieties of Azolla out of which Microfilaria, Finnata is suitable for livestock. 2 kg Azolla per day can be incorporated in the feed of cattle with a reduction in 1kg concentrate per day i.e., about 35%. Azolla can be fed for fish, cattle, buffalo, pig and poultry. Azolla feeding can increase milk yield by 15-20 %

Kitchen garden

Little space is enough for a kitchen garden and can be used for growing seasonal vegetables like green chili, tomato, lady's finger, brinjal.

Mushroom


Mushroom Cultivation

In India button mushroom grown seasonally in environmentally controlled cropping house with proper temperature, relative humidity (80-90%) and ventilation. The leftoverstraw is used for mushroom production after autoclaving and after mushroom cultivation, the spent straw is used as fertilizer for fields. 10-14 kg mushroom cultivation done in 100 kg compost.

Conclusion

With the efficient use of all major and minor components of agriculture with its allied activities, the production per unit area can be increased with increasing the economic status of the farmer with minimal investment per unit area in comparison to the individual farming.

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MANAGEMENT STRATEGIES TO PREVENT PERIPARTUM DISEASES IN DAIRY COWS

Article Id: AL201925

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On rearing high yielding dairy cows, one of the major problems faced by farmers is the peripartum diseases. The peripartum period, the time shortly before, on and after calving is a period of rapid change in the uterus, mammary gland and the metabolism of the animals. Management of cows during the peripartum period can be critical for the mother's health and the effect of good management can be seen in the next lactation period. To achieve "one calf per year" proper care of animals during this period is important. So, the management of peripartum cows involves both welfare issues and potential economic loss, which can be mitigated by improving management during this period.

Peripartum diseases

The majorly affecting peripartum diseases in dairy cows are milk fever, retained placenta, ketosis and dystocia. Most of the periparturient diseases are occurring due to improper nutrition during the periparturient period as it is also called a transition period. The deficiency of either nutritional or non-nutritional management increases the risk for periparturient diseases and other infectious diseases, which ultimately reduces fertility. The fertility of high producing cows is compromised by a poor transition period. A major factor affecting fertility is the level of negative energy balance early postpartum, which may affect the postpartum estrus, timing of first ovulation, oocyte quality and cyclicity. Hypocalcemia is another metabolic disorder frequently affecting the high yielding cows during the postpartum period. If high calcium requirement immediately after calving cannot cope up with the supplement, blood calcium level decreases and leads to hypocalcemia. Calcium is one of the most important minerals needed for muscle contraction and a decrease in the serum calcium level leads to cardiac arrest and finally mortality. Poor feeding during the dry period leads to most of these periparturient diseases.

During the dry period

During this period the mammary gland undergoes physiological atrophy and nearing calving, undergoes hormone-mediated hypertrophy. As the calving time approaches, colostrum starts to accumulate in the udder. The colostrum differs significantly from the normal milk as it contains twice as much calcium, 10 times more vitamin A, three times more vitamin D and 15 times more iron. It also contains more amount of immunoglobulin to protect the newborn calves from infection. During this period, the capacity of the abdomen decreases as the foetal growth is rapid in this period which leads to a significant decrease in feed intake. This period constitutes an important rest period for the mammary gland and the udder undergoes involution and secretory cell regeneration. Proper feeding during this time ensures good body condition of the cows during and after parturition and can prevent the periparturient diseases. Managemental steps to reduce the occurrence of peripartum disease during this period are

1. As the feed intake reduces during this period, more concentrate feed has to be given to compensate for the nutrient requirements for foetal growth.
2. A proper dry period (last 2 months of gestation) has to be provided.
3. Prophylactic supplementation of calcium along with the feed can be given.
4. Administration of intra-mammary antibiotic therapy at the end of lactation can be done to eliminate existing infections and to prevent new ones.
5. Deworming can be done to prevent maternal transmission of parasites to calves.

During parturition


It is generally known that calving causes acutepain in all species, including cows. Around the time of parturition, the levels of acute-phase proteins increase considerably in response to inflammation and tissue damage. Dystocia also can cause severe pain and leads to physiological stress. The pain and stress occur during are important not only because of their negative welfare, but also have a significant effect on the inhibition of oxytocin release thereby reducing myometrial contractions and delay the parturition.Due to the opening of the cervix during parturition, bacteria can enter easily into the uterus and can cause infection.This may lead to metritis and cause septicemia and affect further conception.

Managemental steps to reduce stress during this period are

1. Provide proper clean feed, water and shelter.
2. Provide proper space for resting area of about $11m^2$/cow.
3. Provide clean bedding material to prevent infections.
4. Cows should be transferred to a calving pen during the onset of parturition.
5. Cows should be monitored once an hour from the onset of the first stage of calving soon after the rupture of the amniotic bag.
6. Intervention is required if there is any difficulty is observed.
7. Dams should be allowed to lick and clean the amniotic fluid on the calf.
8. Calves should be provided colostrum immediately after calving.

During the postpartum period

The postpartum period is associated with a high incidence of most periparturient diseases and these may trigger a cascade of other diseases. During this period, the immunity of the dairy cows decreases significantly and are more susceptible to peripartum diseases like metritis and mastitis. Postpartum dairy cows undergo a marked change in energy status as energy output for milk production exceeds energy intake. So, the high energy-rich concentrate should be provided to prevent negative energy balance which may lead to ketosis. Ketosis is a chronic condition and it occurs over a long period of time. It causes neurological symptoms and a decrease in milk yield. Hypocalcemia is one of the major problems in high yielding dairy cows. It causes mortality if not properly treated and it is acute in nature. It occurs mostly within 60 days of calving. Involution of the uterus also occurs during this period and animals returning to the normal restoration of ovarian cycles. Poor body condition at the time of insemination postpartum will affect the conception rate. Preventive measures to be taken during this period are

1. Monitoring the health of cows postpartum carefully upto 10 days for any abnormal in behavior or any other infectious diseases like metritis.
2. Avoid unnecessary use of hormones and antibiotics.
3. Provide proper energy, fibre, proteins, vitamins and minerals rich feed.
4. Retained placenta condition should be treated immediately as it may lead to metritis and septicemia.
5. Teat dips can be used after milking to prevent mastitis.
6. Calcium supplement should be given separately if needed and if the animal has a history of milk fever in the previous calving.

Conclusion

Successful rearing of dairy cows involves both reproduction and nutritional management with standard postpartum health programs to optimize both milk and reproductive performance. Peripartum diseases cause high economic loss to the farmers as it affects both milk yield and reproduction. Metabolic disorders are easy to prevent as they can be easily managed by proper feeding. So, necessary preventive measures have to be taken during the last two months prepartum upto two months postpartum to avoid periparturient diseases. Through proper management, diseases can be reduced and economic loss can be prevented.

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OPTIMUM CONDITION OF WATER FOR AQUACULTURE

Article Id: AL201926

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A large population of India earns its bread and butter from fish cultivation in ponds. But, many times they suffer from production loss due to lack of technical knowledge in this field. It is very important to know the optimum condition of water required for aquaculture. It will help the fish farmers to maintain the pond properly and ensure a better production. In this article, we have briefly described standard conditions for fish cultivation and how it affects production.

Physical condition of pond water

Various physical conditions of pond water are

- Depth of pond.
- Temperature of water
- Light
- Transparency of water

Depth of Pond

Generally, the depth of water in the fish-culture pond should be between 1.5-2 m. If the depth of the pond is too much, then light cannot properly penetrate to the bottom layer of the pond. So, at the bottom of the pond, plants that are light-dependent cannot properly grow. In contrast, if the depth of the fish culture pond is too less then temperature abnormally increases which is very much harmful to the fish.

Temperature of the water

Temperature determines the growth of fish and the nature of soil-inhabiting microbes. Metabolism of the fish body is also largely influenced by the temperature of the water. If the temperature of the surrounding water increases, the metabolism of the body of fish also increases. As a result, the fish grow rapidly. So, fish grow faster in summer than in any other season. Inversely, in winter season fish grow very slowly, as their metabolic rate becomes very slow so they take a very small amount of food. So, in the winterseason, there is very less requirement of food in the fish pond. Generally, the optimum temperature for fish growth in the culture pond is 25-32°C.

Light

In the presence of light, plants present in the water produce food and oxygen, which is very essential to make their habitat compatible for them. The bank of the pond should always clean, clear and plant free so that sunlight directly can penetrate into the water of the pond.

Transparency of water

Water can become turbid due to the presence of mud. So, sunlight cannot properly penetrate into the pond water and photosynthesis of phytoplankton is disrupted in the water of the pond. As a result, the natural food of fish cannot be produced adequately. Moreover, the granules present in the turbid water rapidly absorb nutrient components of water like phosphate, nitrogen etc. resulting in a decrease in fertility of the water of the cultured pond.

Transparency of water is also greatlydecreased due to the presence of excessive phytoplankton and zooplankton. The amount of plankton present in the water should be in a moderate amount. If the density of plankton in the water becomes very high, then oxygen depletion can be seen in the water in the early morning, again if the density of plankton in the water become very less, stunted growth can be seen in fish due to the absence of natural food. The idealtransparency of the water should be between 30-40 cm. Secchi disk is generally used for measurement of the turbidity of pond water.

Chemical condition of pond water

Important chemical components of pond water are

- Dissolved oxygen of pond water
- Dissolved carbon-di-oxide of water
- Total alkalinity
- PH of water
- Nitrogen
- Phosphate
- Hydrogen-sulfide
- Ammonia

Dissolved oxygen of water

Oxygen is the most important component of all living organisms. There are two ways through which oxygen can dissolve in the pond water.

- Surface water of the pond get disturbed
- Oxygen can also be dissolved in the water through the photosynthesis of the aquatic plants present in the water body.

Utilization of oxygen in the pond-

- Fish and other aquatic plants present in the water use oxygen for respiratory activities.
- Oxygen is also used for the degradation of organic matters, present at the bottom of the pond soil.

Dissolved carbon-di-oxide of water

Carbon-di-Oxide is an essential element for plant photosynthesis. But the presence of excess carbon-di-oxide in the pond water is not desirable, as it will cause obstruction for plant respiration. So, we can say that 5-15 mg/l carbon-di-oxide is optimum for fish culture.

Carbon-di-oxide can dissolve in the water mainly from

- Atmosphere
- Respiration of aquatic plants and animals.
- Degradation of organic matter which is situated at the pond bottom soil.

Total alkalinity of water

Generally, the total alkalinity of water is indicated by the carbonate, bicarbonate and hydroxide of calcium and magnesium. The ideal range of total alkalinity of water should between 80-150 mg/l. Application lime is the best solution for the treatment of low alkalinity of pond water.

pH of the pond water

Slightly alkaline water is very much efficient for the culture of fish. But extremely alkaline or acidic water is not desirable for fish culture. Water pH less than 4 and greater than 11 both is lethal for the culture of fish. This pH range of water affects the feed intake capacity of fish as well as their growth. As a result of that fish become vulnerable to different kinds of diseases. The ideal pH range for fish culture is 7.5 to 8.5.

Available Nitrogen of water

Nitrogen is the prime component of protein. So, the presence of nitrogen in the pond water is very much important to increase the productivity of the pond. Nitrogen in the water body comes from the atmosphere in a cyclic pattern through the nitrogen cycle. There are three forms of nitrogen in the water bod. They are Ammonia, Nitrite and Nitrate.

Phosphate, hydrogen sulfide and ammonia

The main sources of phosphate in the water body are the excretoryproducts of organisms, degradation of food materials and phosphate fertilizer. Hydrogen sulfide is a toxic gas, the smell of which is like a rotten egg. Regular application of lime can only eliminate this gas. The presence of excess Ammonia gas is very much harmful to the culture pond of fish.

Conclusion

It is very clear from the above discussion that the successful cultivation of fish requires certain optimum conditions in the pond. The physicochemical parameters of the pond should always be taken care of. Any deviation from the normal conditions can hamper the growth and production of the fish. Good knowledge about the optimum condition will help the fish farmer in obtaining a good production and will also ensure a better economy.

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MYCORRHIZA ENRICHED BIOFERTILIZERS FOR ENHANCING PLANT GROWTH

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Biofertilizers and mycorrhizae are very important to any revegetation effort, as they help to rebuild the living soil that can get damaged by any earthwork. Most desirable species will have a very difficult time out competing weeds without mycorrhizae, or the slowly released nutrients provided by biofertilizers.

Mycorrhizal Fungi

Mycorrhizal fungi form a bridge between the roots and the soil, gathering nutrients from the soil and giving them to the roots. There are two major types of mycorrhizae: Ectomycorrhizal Fungi (EM) and Endomycorrhizal Fungi (AM). While both types penetrate the plant roots, ectomycorrhizae spread their hyphae between root cells, while endomycorrhizae hyphae penetrate root cells. Ectomycorrhizae hosts include members of the Pine, Oak and Beech families, as well as few others in scattered families. Endomycorrhizae are the most common, and are found in grasses, shrubs, some trees, and many other plants.

EM fungi are usually specific to a certain host species, but most species of endomycorrhizae will form relationships with almost any AM host plant, and is therefore much easier to specify. There are four major plant families that usually do not form mycorrhizae: Amaranthaceae (Pigweed family), Brassicaceae (Mustard family), Chenopodiaceae (Goosefoot family) and Zygophyllaceae (Caltrop family). These plant families are well known as weeds. Therefore, if you do not ensure an adequate supply of mycorrhizae, you may inadvertently inhibit growth of desirable species and allow for rapid growth of undesirable species.

Relationships between Biofertilizers and Mycorrhizal Fungi

Plant roots secrete “food” for bacteria and fungi, which attracts nematodes (worms) to the roots, because nematodes eat bacteria and fungi, and excrete Nitrogen, Sulphur and Phosphorus in a form that the plants can use. The nematodes only keep 1/6 of the nitrogen that they process – 5/6 is excreted to the plant. Once the nematodes have excreted the nutrients, the hyphae of the mycorrhizal fungi pick them up and transfer them into the plant. Because of this symbiotic relationship, the least-leachable form of Nitrogen you can apply is bacteria and fungi, and bacteria are the most Nitrogen-rich organisms on earth.

AM hyphae pick up more nutrients than just those excreted by nematodes, however. One of the most beneficial properties of AM mycorrhizae is its ability to “mine” the soil great distances from the roots for nutrients, especially those, such as phosphorus, that are poorly mobile in the soil. AM Mycorrhizae also assist in picking up water further away from the roots, and block pest access to roots. Mycorrhizae also benefit plants indirectly by enhancing the structure of the soil. AM hyphae excrete gluey, sugar-based compounds called Glomalin, which helps to bind soil particles, and make stable soil aggregates. This gives the soil structure, and improves air and water infiltration, as well as enhancing carbon and nutrient storage.

Most natural, undisturbed soils have an adequate supply of mycorrhizae for plant benefits; however, the following practices can reduce mycorrhizae populations to inadequate levels.

Effects of Biofertilizers containing Arbuscular Mycorrhiza fungi on plant growth

The majority of plants growing under natural conditions are associated with mycorrhizae. Mycorrhizal colonization of roots results in an increase in root surface area for nutrient acquisition. The extrametrical fungal hyphae can extend several centimetres into the soil and absorb large amounts of nutrients for the host root (Khan et al., 2000). There is well-documented evidence that Arbuscular Mycorrhizal Fungi (AMF) contribute to increasing availability and uptake of P and micronutrients. The mycorrhizal symbiosis, by linking the biotic and geochemical portions of the ecosystem, can also be regarded as a bridge connecting the root with the surrounding soil microhabitats.

The utilization of microbial products has several advantages over conventional chemicals for agricultural purposes: (i) microbial products are considered safer than many of the chemicals now in use; (ii) neither toxic substances nor microbes themselves will be accumulated in the food chain; (iii) self-replication of microbes circumvents the need for repeated application; (iv) target organisms seldom develop resistance as is the case when chemical agents are used to eliminate the pests harmful to plant growth; and (v) properly developed biocontrol agents are not considered harmful to ecological processes or the environment. Biofertilizers are products containing living cells of different types of microorganisms, which have an ability to convert nutritionally important elements from unavailable to available form through biological processes (Vessey, 2003).

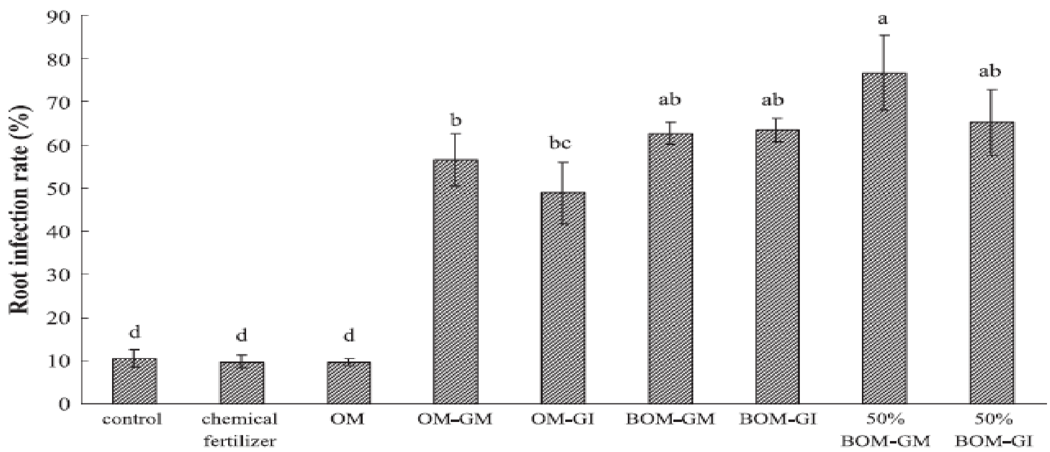
In recent years, biofertilizers have emerged as an important component of the integrated nutrient supply system and hold a great promise to improve crop yields through environmentally better nutrient supplies. However, the application of microbial fertilizers in practice, somehow, has not achieved constant effects. The mechanisms and interactions among these microbes still are not well understood, especially in real applications. Wu et al. (2005) conducted an experiment to see the effect of mycorrhiza fungi on the growth of maize and they found that the mycorrhizal inoculum significantly increased the extent of AMF colonization of the root system compared to the uninoculated control treatments.

The inoculation with beneficial bacteria and low fertilization level increased root colonization by both G. mosseae and G. intraradices. It has already been noted that the rhizobacteria can act as dmycorrhization helper bacteria T, which improve the ability of mycorrhizal fungi to colonize plant roots. The mechanisms by which these bacteria stimulate AM colonization are still poorly understood. Specialized bacterial activities such as the production of vitamins, amino acids, and hormones may be involved in these interactions. The presence of rhizobacterial inoculation might have assisted in the germination of a large number of spores thus leading to a higher infection percentage. Some PGPR endophytic species are known to have cellulose and pectinase (Verma et al., 2001) and these activities could not doubt aid in mycorrhizal infection.

The present results demonstrated that the population size of the inoculated rhizobacteria varied in accordance with the levels of fertilization and AMF colonization in the rhizosphere (Fig. 1). The low level of fertilization (50% BOM+GM and 50% BOM+GI) resulted in a higher level of mycorrhizal root infection and a larger community of A. chroococcum in the rhizosphere, compared to the treatments with a high level of fertilization

(BOM+GM and BOM+GI). According to our preliminary results (in preparation the propagation of A. chroococcum was seriously inhibited when the Ammonium N concentration exceeded 200 mg kg-1. However, a sharp decline of the number of P and K solubilizers (with a decrease rate of 42.3% and 25.5%, respectively) was observed with the increase of G. mosseae colonization level.

It implies that maize is likely more dependent on the symbiosis with G. mosseae than P solubilizers under the condition of insufficient nutrient supply, e.g. when P deficiency occurs. Toro et al. (1997) reported a drop of density in the introduced P-solubilizing bacteria from 106 to 103 cfu g-1 soil in the rhizosphere with the increase of root mycorrhizal colonization. By contrast, the colonization with G. intraradices showed a strong stimulating



effect on the propagation of these two solubilizers. Mycorrhizal colonization with G. mosseae allowed the introduced populations of beneficial soil microorganisms like Azotobacter, Azospirillum and

Figure 1: Plant root infection rate by arbuscular mycorrhiza fungi in different treatments

phosphate-solubilizing bacteria to maintain a higher abundance than non-mycorrhizal plants and thereby exerted a synergistic effect on plant growth.

In practice, good indigenous species are preferable to be selected as inocula in order to ensure a successful colonization of mycorrhizae since the possible competition may occur between introduced and autochthonous populations in unsterilized field soil conditions.

Enhancement of alkalinity tolerance in two cucumber genotypes inoculated with an arbuscular mycorrhizal biofertilizer containing Glomus intraradices

Yossef et al. (2010) conducted an experiment and suggested that to avoid or reduce losses in production caused by alkalinity in high yielding genotypes would be to inoculate them with arbuscular mycorrhizal fungi capable of reducing the detrimental effect of external pH on crop performance. Arbuscular mycorrhizal fungi are the most widespread root fungal symbionts and are associated with the vast majority of higher plants (Sensoy et al., 2007). Arbuscular mycorrhizal fungi have been shown to improve soil structure, enhance plant nutrient acquisition (P, N, Zn, Cu, and Fe), overcome the detrimental effect of salinity, improve drought tolerance, suppresses root knot nematode (Zhang et al., 2008), and alleviate cultural and environmental stresses through greater effective root area and penetration of substrate (s) and activation and excretion of various enzymes by infected arbuscular mycorrhizal fungi roots and/or hyphae.

However, the benefits of arbuscular mycorrhizal fungi inoculation depend on the specific host–fungus combinations and also on the types of the inoculums used. Enhancing the tolerance of plants to alkalinity when inoculated with AM fungi has been studied and proposed until now for ornamental crop production such as vinca and roses, whereas no published data is available on the effect of arbuscular mycorrhizal fungi inoculation under high pH conditions on the agronomical and physiological responses of an important vegetable crop widely grown in the Mediterranean region, such as cucumber. Differences in mycorrhizal responsiveness between different crops and between different genotypes within the same crop have also been demonstrated. In wheat, growth of modern cultivars tended to benefit less from mycorrhizal inoculation than older cultivars. Similarly, improved soybean cultivars showed a lower growth response to colonization than older cultivars.

No consistent trend has been observed among corn cultivars. Cultivated tomatoes and oats, however, are more responsive to mycorrhizal colonization than closely related wild species. We hypothesize that arbuscular mycorrhizal inoculation with a biofertilizer containing Glomus intraradices would give an advantage to overcome alkalinity problems. To verify this hypothesis, two cucumber genotypes (hybrid or open-pollinated variety) were inoculated and their yield, growth, fruit quality, net photosynthesis, electrolyte leakage, and mineral composition were compared with those of noninoculated plants when both were grown in sand culture at two pH values in the nutrient solution (6.0 or 8.1). Under alkaline conditions, yield and biomass production were higher in inoculated than noninoculated plants.

Alkalinity tolerance of cucumber plants inoculated with G. intraradices may be due to the better uptake and translocation of mineral elements in particular P, Mg, Fe, Zn, and Mn to the shoot. Arbuscular mycorrhizae can mitigate growth reduction by alkalinity (Cartmill et al., 2007) but the mechanism involved remains unresolved. Cartmill et al. (2007) concluded that the alkaline tolerance of Rosa multiflora is primarily related to the enhanced nutrient uptake (N, P, K, Ca, Fe, Zn, Al, and B), leaf chlorophyll concentration, low Fe reductase activity, and low soluble alkaline phosphatase activity. Similarly, Cartmill et al. (2008) stated that the tolerance of vinca plants inoculated with a mix (ZAC-19) of Glomus species isolate (Glomus albidum, Glomus claroideum, and Glomus diaphanum) to alkalinity was associated with increased P uptake due to a higher soluble phosphatase activity at moderate HCO3- concentrations, with the maintenance of other leaf nutrients when HCO3 − increased up to 10 mM, and with an increase of antioxidant activity, and thus detoxifying activity, probably as a result of their enhanced micronutrient status.

In many plant species, the high alkalinity induces Fe deficiency due to reduced Fe availability in soil or uptake. Bicarbonate can also precipitate Fe internally making this nutrient less available in roots (Römheld 2000). We have shown that the increase in the concentration of NaHCO3 from 0 to 10 mM in the nutrient solution significantly decreased the leaf Fe concentration by 39%, but inoculated plants accumulated on average 14% more Fe than noninoculated plants. This suggests that arbuscular mycorrhizal inoculation with a biofertilizer containing G. intraradices enhance the uptake and translocation of Fe toward the shoot. The higher uptake and accumulation of Fe in inoculated than noninoculated cucumber plants was the main mechanism reducing the detrimental effect of alkalinity (Fe deficiency) on yield and plant growth. Iron deficiency can cause various physiological changes in leaves, as iron is an important cofactor of many enzymes, and interferes with several aspects of plant biochemistry, including photosynthesis and pigment synthesis.

Influence of inoculation with arbuscular mycorrhizal fungi on the growth and mycorrhizal infection of transplanted onion

There is increasing interest in using arbuscular mycorrhizal (AM) fungi in agricultural and horticultural crop production. Recently, the possible use of mycorrhizal inoculation in sustainable agriculture was discussed. The benefits of symbiosis are particularly enhanced uptake of immobile nutrients, improvement of drought tolerance and disease resistance. Some studies revealed a stimulatory effect of mycorrhizal fungi on the growth and nutrient uptake of onion in pot and field experiments. The growth of plants may be considerably enhanced by inoculation with suitable AM fungi, particularly if levels of available soil phosphorus are low (Powel, 1984). In commercial practice, however, the crop is often over-fertilised, because the cost of P fertiliser is trivial relative to the large profit margin from this crop.

Nevertheless, as was shown by Nelsen and Safir (1982) the vegetative growth of onion mycorrhizal seedlings was less affected by drought than that of nonmycorrhizal seedlings. This effect is of potential importance in the field because growth of onions could be markedly reduced by lack of water. The number of field studies using the mycorrhizal inoculation in non-sterilised soils is limited. Where field soils are fumigated and most of the indigenous mycorrhizal fungi are killed, mycorrhizal inoculation is often successful. However, the inoculation in non-sterilised soils could also be beneficial because of the addition of a more efficient strain of the fungus or to more rapid infection rates. The transplants can be inoculated with pure strains of highly effective AM fungi, giving the introduced strains a competitive advantage over strains of indigenous fungal population in the field soils. Inoculation of plants seedlings before transplanting may increase crop uniformity, reduce transplant mortality and improve growth.

Miroslav Voshtka (1995) conducted five field experiments and suggested that the stimulatory effect of mycorrhizal inoculation was found in almost all experimental treatments. This effect is more apparent in previously sterilised soil where competition with native indigenous endophytes is reduced or eliminated. The best way to eliminate the indigenous population of fungi seems to be by steam sterilisation rather than by fumigation with Basamid. Nevertheless, when experiments 1, 2 and 3 are compared (although they were conducted in different years) it seems that steam sterilisation could probably inhibit later mycorrhizal infection of later transplanted inoculated seedlings. Comparing the infection of control and Glomus intraradices inoculated plants from all three experiments higher values were found in non-sterilised than fumigated soil and the lowest in the steam sterilised soil. These differences might be caused by some climatic variability between years.

The experiments were conducted on the same field and also the growth of plants was comparable, except in the third experiment when the plants grew a little better. Therefore, the degree of sterilisation was probably the prevailing factor affecting the performance of indigenous and introduced fungal symbionts of transplanted plants. The findings of Snellgrove and Stribley (1986) about growth inhibition or substantial mycorrhiza reduction or elimination from Basamid fumigation were not found. The extent of positive growth response in all experiments is in agreement with results reported by others. Furlan and Bernier-Cardou (1989) found a 41% increase following inoculation by Gigasporacalospora. Snellgrove and Stribley (1986) reported bulb yield increases of up to two times after inoculation by Glomus mosseae and Powel (1981) observed a 92% increase of onion shoot biomass as a result of mycorrhizal inoculation.

The most effective symbionts over all experiments were Glomus intraradices and Glomus etunicatum. The latter has been used previously in pot trials with onion, but did not increase the growth of plants. The results correspond with findings of Snellgrove and Stribley (1986) who found a positive effect of pre-inoculation on the production of bulbs with diameter higher than 20 mm. Negative correlations between higher soil-available phosphorus content and mycorrhizal growth response has been reported. In the fifth experiment, fertilisation increased soil P content and irrigation most probably enhanced P availability because of better diffusion in moist soil.

Both these treatments decreased the positive mycorrhizal growth response. This decrease was more apparent for shoots than bulb yield. Mycorrhizal plants might allocate more biomass to the bulbs where the nutrient requirement is probably higher. These results are similar to those reported for pot-grown onions but are in contrast to the findings of Snellgrove and Stribley (1986) who found a positive correlation between irrigation and mycorrhizal growth response. When the plants are not fertilised and irrigated, the soil nutrient diffusion is low and some nutrients, particularly phosphorus, become the limiting growth factor.

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