Complete Book-min

1 author:

Deiva Sigamani
KRISAT

ADVANCES IN AGRONOMY

VOLUME - 17

Chief Editor

Dr. Anay Kumar Rawat
Scientist and Technical Officer (Administration) to Vice Chancellor
JNKVV, Jabalpur, Madhya Pradesh, India

Co-Editor

Uttam Kumar Tripathi
Scientist (AE), Deendayal Research Institute, Krishi Vigyan Kendra, Satna, India

AkiNik Publications
New Delhi

Published By: AkiNik Publications

AkiNik Publications
169, C-11, Sector - 3,
Rohini, Delhi-110085, India
Toll Free (India) – 18001234070
Phone No. – 9711224068, 9911215212
Email – akinikbooks@gmail.com

Chief Editor: Dr. Anay Kumar Rawat
Co-Editor: Uttam Kumar Tripathi

Publication Year: 2022

Pages: 94

ISBN: 978-93-5570-027-8

Book DOI: https://doi.org/10.22271/ed.book.1671

Price: ₹ 704/-

Message

The challenges before the scientists and farmers of our country today are much more complex than even before. Food production has to be increased to 240 m.t. within the next five years which is really herculean task. Crop production and production technologies for the same area of utmost importance to meet out the task.

Management of natural resources like soil and rainwater for improved productivity of crops and livestock holds the key for higher income and better livelihoods for the vast majority of farmers. Enhancing productivity of unit land in rainfed as well as irrigated areas is the pre-requisite for producing more cereals, pulses, oilseeds, vegetables, fruits, eggs and milk, which are at present in short supply. Under such state of affairs, important and relevant information were collected and compiled in a book form titled "Advances in of Agronomy - Vol-17". This book is mainly intended for graduate, post graduate students, researchers and extension workers in the field of Agriculture, Horticulture, Home science, Forestry and Agricultural Engineering. The present book was written as per the need of the farming community.

This book is written in simple language dealing with various current topics related to agronomy. This book has been prepared with an objective to complied all the information at a glance about agronomy. We are sure that this book will serve as valuable text cum reference book to all who are linked with agriculture.

We are very much thankful for all the authors who contributed for this book. In spite of the best efforts, it is possible that some errors may have left into the compilation. The readers are requested to kindly let us know the mistakes so that these could be taken care of in the further edition. Finally, we thank our AkiNik Publications for bringing out this book so efficiently and promptly.

Dr. Anay Kumar Rawat
Uttam Kumar Tripathi

Contents

Chapter - 1
Improving Water Productivity in Conservation Agriculture

Authors

Girija Prasad Patnaik
Department of Agronomy, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

G. Srinivasan
Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

K. Subash Chandra Bose
Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

S. Sapthagiri
Department of Agronomy, Nammaazhvar College of Agricultural and Technology, Kamuthi, Tamil Nadu, India

S.V. Varshini
Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

M. Jeeva
Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Chapter - 1

Improving Water Productivity in Conservation Agriculture

Girija Prasad Patnaik, G. Srinivasan, K. Subash Chandra Bose, S. Sapthagiri, S.V. Varshini and M. Jeeva

Abstract

Agriculture accounts for 70% of all water withdrawals globally. Irrigated land is more than twice as productive as rainfed crop land. Water use in agriculture is at the core of any discussion of water and food security. The World Bank helps countries improve water management in agriculture to achieve Sustainable Development Goals on efficient use of water as well as on eliminating hunger. Currently, water use is unsustainable; water supplies are limited being affected by climate change. Much effort was made to reduce water use by crops and produce 'more crop per drop' (improving crop water productivity) and it can be led through improvements in agronomic practices by choosing well-adapted crop types, mulching, zero tillage/minimum tillage and reducing unproductive sinks *viz.*, seepage, percolation and evaporation. It provided additional impetus for the researchers to solve the problems arising from the mismatch between demand and supply in terms of water quantity, quality and timing. Improving water productivity was identified as one of the global challenges that require urgent attention. Conservation agriculture enhances biodiversity and natural biological processes above and below the ground surface, which contribute to increased water and nutrient use efficiency. CA had an improved remarkable achievement in both sustained investment in agricultural research and development and farmer innovation.

Keywords: Crop water productivity, mulching, tillage, conservation agriculture

Introduction

Water is a most important key input for agriculture production. Irrigated agriculture is the largest water-consuming sector and it faces competing demands from other sectors, such as industrial and domestic sectors. The world had finite water resources, which are under increasing stress as the human population and water demand per capita both increases and less water available for agricultural production. Thereby, the food security for future generations is at risk, it becoming more wide spread and devastating. Likely, that 78% of the world population will live in areas facing physical and economic water scarcity by 2025 (IWMI, Colombo). The agricultural sector faces the challenge to produce more crops per drop of water for increasing Crop Water Productivity (Kijne *et al*., 2003).

Crop Water Productivity is generally defined as the ratio of total amount crop yield (output) per cubic meter of water consumed (input), including 'green' water (effective rainfall) for rainfed areas and both 'green' water and 'blue' water (diverted water from water systems) for irrigated areas. Globally, storage and transfer losses are estimated at approximately 30% (Wallace and Gregory 2002). Run-off and drainage losses may represent another 44%, which means that after accounting for soil evaporation losses probably only some 13-18% of water available for irrigation ends up in transpiration (Wallace and Gregory 2002; Gregory 2004). To reduce water degradation and to reallocate water to higher priority uses for maintaining healthy, vigorously growing crops through optimized water, nutrient and agronomic measures.

History of conservation agriculture

Year	Development	Reference
1930	Great dust bowl and start of conservation agriculture in the USA	Hobbs *et al*., 2008
1940	Development of direct seedling machinery, first no-till sowing	Friedrich *et al*., 2012
1943	Book on no-till in modern agriculture entitled "Plowman's Folly" by Faulkner	Faulkner, 1943
1950	No-till, direct-sowing of crops was first successfully demonstrated in the USA	Harrington, 2008
1956	Experiments on various combinations of tillage and herbicides were initiated	Lindwall and Sonntag, 2010
1960	Commercial adoption of no-till in the USA	Lindwall and Sonntag, 2010 Friedrich *et al*., 2012
1962	Paraquat was registered as first herbicide for broad spectrum weed control	Lindwall and Sonntag, 2010
1962	Long term no till experiments were started in Ohio, USA	Perszewski, 2005
1964	First no-till experiments in Australia	Barret *et al*., 1972
1966	Demonstration trials on direct drilling systems in Germany	Baumer, 1970
1967	Demonstration trials on direct drilling	Cannel and Hawes., 1994

	systems in Belgium	
1968	First no tillage trials in Italy	Sartori and Peruzzi., 1994
1969	Introduction of CA in West Africa	Greenland, 1975; Lal, 1976
1970	First no-till demonstration in Brazil	Borges, 1993
1973	Phillips and Young published the book "No-tillage Farming" -milestone in no-tillage literature, being the first one of its kind in the world	Derpsch, 2007
1974	First no-till demonstration in Brazil and Argentina	Friedrich *et al.*, 2012
1975	Book on CA entitiled "One straw revolution" by Fukuoka	Fukuoka, 1975
1976	Glyphosate was registered as general broad spectrum weed control	Lindwall and Sonntag, 2010
1980	Introduction and on-farm demonstration of CA in subcontinent	Harrington, 2008
1980	Introduction of CA to Zimbabwe	Friedrich *et al.*, 2012
1981	The first National No-Till Conference held in Ponta Grossa, Parana, Brazil	Derpsch, 2007
1982	Introduction of no-till in Spain	Giraldez and Gonzalez, 1994
1990	Development and commercial release of reliable seeding machines	Lindwall and Sonntag, 2010
1990	Commercial adaptation of CA in southern Brazil, Argentina and Paraguay	Friedrich *et al.*, 2012
1990	Introduction of CA to India, Pakistan and Bangladesh	Friedrich *et al.*, 2012
2002	Introduced no-tillage systems in Kazakhstan	Derpsch and Friedrich, 2009

Worldwide adoption of conservation agriculture

Country	**Area (mha)**
USA	35.6
Brazil	31.8
Argentina	29.2
Canada	18.3
India	1.5
World	157

Source: FAO, 2015.

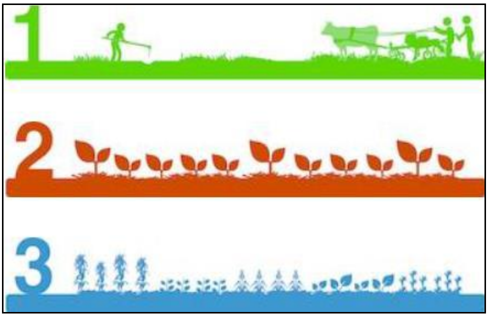
Conservation agriculture (ca) definition and goals

Conservation agriculture does not promote a specific technology but rather a series of principles and general practices to achieve conservation objectives, through an agronomic integrated practice of no-tillage, laser leveling, direct seeding, application of mulch (live mulch or dead mulch) and intercropping, which is increasingly propagated amongst smallholder rainfed agriculture communities in Sub Sahara Africa. Its function is to protect the soil physically from sun, rain and wind and to feed soil biota. Conservation agriculture is a farming system that can prevent losses of arable land while regenerating degraded lands. Protagonists proclaim the beneficial effects of CA as an ecosystem based agronomic practice that benefits the fertility, productivity and water harvesting of the cropping systems, with low input requirements.

To increase CWP through the principle of same production from less water resources or a higher production from the same water resources. Therefore, in addition to increase in crop yield, application of organic manures decreases the amount of water used in the production process and increases crop water productivity substantially (Bezborodov *et al*., 2010). Improved agricultural productivity using conservation agriculture (CA) systems based on non-inversion tillage methods, have predominantly originated from farming systems in sub-humid to humid regions where water is not a key limiting factor for crop growth and development. To increase the yields and improved water productivity can be achieved by using conservation agriculture in semi-arid and dry sub-humid locations in Ethiopia, Kenya, Tanzania and Zambia (Rockstroma *et al*., 2009). Conservation agriculture (CA) is an approach developed to manage the agricultural land for sustainable crop production, while simultaneously, preserving soil and water resources (Erenstein, 2011).

Principles of conservation agriculture

Conservation agriculture practices perused in many parts of the world are built on ecological principles making land use more sustainable (Wassmann, 2009; Behera *et al*., 2010; Lal, 2013). Adoption of CA for enhancing Resource use efficiency (RUE) and crop productivity is the need of the hour as a powerful tool for management of natural resources and to achieve sustainability in agriculture. Conservation agriculture basically relies on 3 principles, which are linked and must be considered together for appropriate design, planning and implementation processes. Conservation agriculture technologies involves,



1) Minimum soil disturbance.
2) Permanent soil cover through more than 30% crop residues or cover crops.
3) Crop rotations (diversification) for achieving higher productivity. (FAO 2013; Derpsch 2008; Hobbs *et al*., 2008; Kassam *et al*. 2009).

Difference between conventional agriculture and conservation agriculture

SL. No.	Conventional Agriculture	Conservation Agriculture
1.	Cultivating land, using science and technology to dominate nature	Least interference with natural processes
2.	Greater NO_3 and nutrient losses in Groundwater deep percolation Pollution	Clean water drained
3.	Periodically bare soil	Permanent soil cover (organic residues)
4.	High temperature fluctuations	More stable temperatures throughout the day and the year
5.	Intense nutrient leaching under the root zone, deep water pollution	Efficient nutrient and water cycling
6.	Unstable mechanical porosity	Stable/high biological activity and adequate soil porosity
7.	Root system, weed seed and organic residues mostly in the tilled layer	Deep and diverse root system
8.	Contributes to soil organic matter SOM degradation	Intense downward and upward movement to soil fauna
9.	Intense water runoff and soil erosion. Loss of SOM (oxidation by microorganisms)	Very low risk of soil erosion (no splash effect to rain drops, better infiltration, limits runoff)
10.	Excessive mechanical tillage and soil erosion	No-till or drastically reduced tillage (biological tillage)
11.	High wind and soil erosion	Low wind and soil erosion
12.	Residue burning or removal	Surface retention of residues

		(permanently covered)
13.	Water infiltration is low	Infiltration rate of water is high
14.	Use of ex-situ FYM/composts	Use of in-situ organics/composts
15.	Green manuring (incorporated)	Brown manuring/cover crops (surface retention)
16.	Kills established weeds but also stimulates more weed seeds to germinate	Weeds are a problem in the early stages of adoption but decrease with time

Minimal mechanical soil disturbance

The soil biological activity produces very stable soil aggregates as well as various sizes of pores, allowing air and water infiltration. This process can be called "biological tillage" and it is not compatible with mechanical tillage. With mechanical soil disturbance, the biological soil structuring processes will disappear. Minimum soil disturbance provides/maintains optimum proportions of respiration gases in the rooting-zone, moderate organic matter oxidation, porosity for water movement, retention and release and limits the re-exposure of weed seeds and their germination (Kassam and Friedrich, 2009).

By adopting continuous no-till/minimum tillage and using residue management, more water is available for crop production. If producers don't change their cropping practices to make use of that water, they may complain that no-till soils are too cold and wet. If their soils cannot store all the water is when it is available, deep percolation may occur, potentially leaching nutrients out of the root zone. Examples of changes to use the "extra" water include: increasing seeding and fertilizer rates for higher yields; implementing more intense and diverse crop rotations; using cover crops, relay cropping or double cropping and for irrigators, applying less irrigation water. Reduced or no till system sequesters higher fractions of C and principles along with a systemic approach, can significantly contribute to improve the water-soil-plant multiple relationship (soil physical, chemical and biological properties) and at the same time be improving the general agro-ecosystem productivity and sustainability (Jat *et al*., 2009). Precise application of water onto plant roots which could result to reduced water and energy cost, less disease pressure because the leaves remain dry and better weed control while soil erosion can be avoided (Palada *et al*., 2011).

No-Tillage as a Way OF Reducing Water Footprint		
⇩	⇩	⇩
Green water	Blue water	Grey water
Reduce evaporation. Increased water holding capacity. More available soil moisture. Increased infiltration.	Reduce run off. Reduce water erosion More constant flow in river/stream. Improve recharge of the water table.	Clean water because pollution, erosion and sedimentation of water bodies are reduced. Reduced fertilizer and pesticide use. Herbicide use might be increased.

Green water

No-tillage systems are very effective in reducing evaporation from soil, to increase the water holding capacity and soil moisture and increase water infiltration. The use of soil covers reduces water evaporation and therefore water is available for crop production. No tillage systems increase soil water infiltration substantially compared to the infiltration of the moldboard-ploughed soil. The covered surface of no-tillage fields acts as a protective skin for the soil. This soil skin reduces the impact of raindrops and buffers the soil from temperature extremes as well as reducing water evaporation.

Blue water

No-tillage systems are very effective to reduce runoff, water erosion, improved recharge rate of the water table and allow more constant flow in the river stream. When rain drops hit the soil they destroy soil aggregates so that tiny soil particles clog the pores impeding water to infiltrate the soil, and hence it may reduce water runoff. The increase in green water reduces the need of blue water to satisfy the water crop requirement. According to Peiretti, under irrigated conditions no-tillage significantly contributes to reducing the amount of water needed for crop production. That means farmers can save on irrigation and, just as importantly, this reduces water logging of the crop. Water savings of 15-50% have been calculated under no-tillage systems. Moreover, in China, water use efficiency has increased (with upto 35%) following the implementation of reduced tillage practices. By reducing evaporation of soil moisture reserves and by improving soil water infiltration, irrigation needs can be reduced under CT. To ensure a reduction of blue water, competition for water from weeds needs to be restricted.

Grey water

Water quality may be improved in no-tillage if fertilizer and pesticide use is minimised, clean water is drained and pollution, sedimentation and erosion are reduced. Permanent soil increases water infiltration, hence water runoff and soil erosion risks may be reduced. The reduction of water runoff and the consequent reduction or avoidance of soil erosion implies a better water quality of surface water as fewer nutrients are carried by the runoff.

Permanent organic soil cover

Growing a cover crop during all time of the year is a crucial concept for improving water and nutrient cycling, soil health, soil protection and building organic matter. A permanent soil cover is important to protect the soil against the deleterious effects of exposure to rain and sun; to provide the micro and macro organisms in the soil with a constant supply of “food”; and alter the microclimate in the soil for optimal growth and development of soil organisms, including plant roots. In turn it improves soil aggregation, soil biological activity and soil biodiversity and carbon sequestration, reduce surface crusting and sealing with enhanced water infiltration, decreased runoff and break through compaction layers in deeper in the soil (Ghosh *et al.*, 2010). Crop residue and growing vegetation protects the soil surface from erosion by absorbing the energy of raindrop impact and reducing soil particle detachment. Mulching helped in conservation of the soil moisture (Bhatt and Khera, 2006), regulates the soil temperature (Singh *et al.*, 2011) and in all improves the water productivity (Kukal *et al.*, 2014). Some cover crops such as cereal rye can help suppress certain weed, i.e., marestail along with forage harvest system. Further, the presence of mulch layers in conservation agriculture resulting in high accumulation of soil organic carbon (Thiombano and Meshack 2009; Silici 2010).

Advantages of mulching/soil cover

- Water runoff is reduced, which is beneficial in two ways: more water is available for the crop and soil erosion is reduced.
- Reduced wind and water erosion.
- Reduced erosion can lead to off-site benefits such as a reduced rate of siltation of water courses and increased recharge of aquifers.
- Increased water infiltration into the soil and increased soil moisture.
- Reduce evaporation losses.

Maximum wheat yield and WUE in the field were recorded with plastic film and crop residue mulching (Zhang *et al*., 2013). Mulching with crop residues can improve water-use efficiency by 10-20% through reduced soil evaporation and increased plant transpiration. Mulching with crop residues during the summer fallow can increase soil water retention (Wang *et al*., 2004).

Diversified crop rotations

The rotation of crops is not only necessary to offer a diverse “diet” to the soil micro organisms, but also for exploring different soil layers for nutrients that have been leached to deeper layers that can be “recycled” by the crops in rotation. Furthermore, a diversity of crops in rotation leads to a diverse soil flora and fauna. Cropping sequence and rotations involving legumes helps in minimal rates of build-up of population of pest species, through life cycle disruption, biological nitrogen fixation, control of off-site pollution and enhancing biodiversity (Kassam and Friedrich, 2009; Dumanski *et al*., 2006). It also reduce nitrate leaching over conventional tillage, as well as proper crop rotation, especially those including a nitrogen-fixing crop. However, it showed that conservation tillage also increased the infiltration rate of soils.

Water productivity

Productivity is a measure of performance expressed as the ratio of output to input, producing more food, income, livelihoods, and ecological benefits at less social and environmental cost per unit of the agro-input (or water). Water productivity (WP) and land productivity measures how the system converts water into goods and services. The value of product might be expressed in different terms (biomass, grain, money) approach focuses on the amount of product per unit of water. WP refers physical mass of production or the economic value of production measured against gross inflow, net inflow, process depleted water. The water accounting methodology developed by IWMI (Molden, 1997 and Molden and

Sakthivadivel., 1999). WP expressed in the terms of kg /m^3 of water or INR/m^3 of water.

Key principles for improving water productivity at field, farm and basin level, for both rainfed and irrigated conditions are

- Increase the marketable yield of the crop for each unit of water transpired by it.
- Reduce all outflows (e.g. drainage, seepage and percolation) including evaporative outflows other than the crop stomatal transpiration.
- Increase the effective use of rainfall, stored water, and water of marginal quality.

The definitions of the terms adopted in the study are expressed as follows,

$$\text{WP (Gross inflow)} = \frac{\text{yield}}{\text{gross inflow}}$$

Where, Yield (Kg/ha), Gross inflow, (m^3 /ha)

Weight of grains over cumulative weight of water inputs by irrigation and rain during crop growth

$$\text{WP (irrigation inflow)} = \frac{\text{yield}}{\text{irrigation inflow}}$$

Where, Yield (Kg/ha), Irrigation inflow (m^3 /ha)

$$\text{WP (process depletion)} = \frac{\text{yield}}{\text{evapotranspiration}}$$

Where, Yield (kg/ha), Evapotranspiration (m^3 /ha)

Volume of water delivered at the source (m^3) = Tube well discharge (m^3/s) x hrs of irrigation x 3600

Volume of water delivered at the field (m^3): = discharge by Parshall flume (m^3/sec) x hr of irrigation x 3600

Or (Tube well discharge-seepage losses) (m^3/sec) x hrs of irrigation x 3600

Total volume of water (m^3) = Volume of delivered at field (m^3) + total volume of rain fall water (m^3)

Deep percolation (m^3) = Total volume of water (m^3)-actual evapotranspiration (m^3)

Water balance

Water balance of a cropped field is calculated as follows:

I+R= ET+P+S (cm)

Where R is the rainfall, I the irrigation, ET the Evapotranspiration, P is the deep Percolation loss, S is the seepage.

Potential for new investments in water management techniques

- Capturing more water and allowing it to infiltrate into the root zone.
- Using the available water more efficiently (increasing water productivity) by increasing the plant water uptake capacity and/or reducing non-productive soil evaporation (Rockstrom, 2003).

Improving efficiency of irrigation systems

There is a need for better and efficient use of irrigation and rainwater to improve water use efficiency, through minimize the deep percolation losses to 45-50% for increasing the water productivity (Kumari Namrata and Ravish Chandra, 2019). This indicates that about 4.35, 0.675 m^3 of supplied water were used to produce one kilogram of rice, wheat respectively, and thus presents a great potential for conserving water for rice irrigation. Besides the variation in crop to be irrigated, the source of irrigation water also had major role for conserving/saving water and thus improve the water productivity. Generally, irrigation with groundwater was found to be more efficient due to better control over the amount and timing and manageable flows (Kumar *et al*., 2008). The concept of water footprint is defined as the total volume of freshwater used directly or indirectly, to produce a product or process including the total amount of water required in agriculture for growing crops. Management practices should only be chosen after a thorough evaluation of their potential impacts and side-effects.

Resource conservation technologies (RCTs)

RCTs include zero tillage (or reduced/minimum tillage), laser land levelling and furrow bed planting had the effectiveness of RCTs in reducing water application between 23% and 45% while increasing yield, especially at field (Kahlown *et al*., 2006); Water savings of 30% due to the adoption of zero tillage in rice-wheat systems (Hobbs and Gupta, 2003); 25% to 30% water savings (Gupta *et al*., 2002) and 20% to 35% savings in irrigation water (Humphreys *et al*., 2005) under zero tilled wheat compared to conventionally tilled in the rice-wheat belt of the Indo-Gangetic plains.

Moreover, farmer surveys showed that their primary reasons for adopting the two technologies were:

- To increase profitability (97% of adopter's respondents).
- To cope with water scarcity (87% respondents).

Coping with water scarcity is itself related to profitability, because it is strongly linked with productivity and the cost of groundwater pumping. Both zero tillage and laser levelling are perceived by Pakistan Punjab farmers to result in substantial savings in water application (24% for zero tillage and 32% for laser levelling), fuel (52% and 16%) and labor (52% and 14%). Because of the decrease in input use, almost all adopters (87% for zero tillage and 88% for laser levelling) reported a decrease in production costs. The impacts of RCTs on wheat yields were varied, with about 54% farmers reporting an increase, 30% a decline and 16% no change for zero tillage. The comparative numbers for laser levelling were 96%, 0% and 4%, respectively. With generally increased yields and decreased costs, net crop income on fields using the two RCTs rose for majority of farmers, providing good evidence for the large-scale adoption and popularity of the two technologies in the Indus-Gangetic basin (IWMI Primary surveys in Pakistan Punjab, Ahmad *et al*., 2007). This was very well reflected in improved water productivity under bed planted wheat as compared to conventionally planted wheat.

Conservation tillage is a systems approach that provides benefits such as reduced fuel usage, improved soil quality, and reduced erosion. But perhaps one of the most important aspects, water savings, is often overlooked**.** Considering that 49%, 55% and 75% of cotton, corn and peanuts receive irrigation, conservation tillage can save a significant amount of water and energy. Conservation tillage systems, through the use of cover crops and reduced tillage, increases water infiltration by as much as 30 to 45% compared to conventional tillage systems for loamy sand and sandy loam soils.

Conservation agriculture with drip irrigation

The combination of CA with drip irrigation, water is directly applied to the plant rooting zone, thus minimizing evaporation from the surface and can thus increase the crop productivity and potentially increase water use efficiency by atleast 50%, enhance soil ecosystem and health, reduce weeds, enhance the quality of leafy and fruit vegetable, and increase the yield and quality. The improvement of soil quality and structure due to CA practice, adding nutrients to the soil and sticking soil particles together (increase soil aggregates). Irrigation water productivity for tomato under CA (5.17 kg/ m^3 in CA as compared to 1.61 kg /m^3 in conventional tillage is found to be higher when compared to water productivity for the other vegetables such as garlic, onion and cabbage (Tewodros *et al*., 2019).

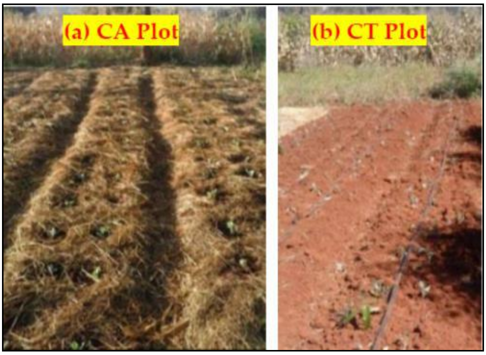


Fig 1: Experimental design and setup Conservation agriculture (CA) plot (a) and Conventional tillage (CT) plot (b)

Significant improvement in irrigation water productivity and crop yield was observed under CA practice due to the improvement of soil structure (sticking soil particles together and increase soil aggregates) and quality (adding nutrients). As the organic mulch gets decomposed, soil organic matter is formed. Soil organic matter invites heroes of the soil world; worms, bacteria and fungi. As the soil organic matter gets decomposed, it provides nitrogen and phosphorus to the vegetables (improving soil quality). The microorganisms use the organic matter as a food and produce chemicals which can stick the soil particles together and form an aggregate (improving soil structure). On the other hand, the addition of mulch reduces soil evaporation, surface runoff, and erosion. The combined effects of CA resulted in lower irrigation need (18 to 46% reduction) with higher crop yield (9 to 184% increased) for various vegetables when compared to CT.

Opportunities and Challenges

Several opportunities came into perspective when adapting CA with drip irrigation for smallholder farmers.

- **Reducing labor:** Farmers experienced reduced labor when growing vegetables in CA with a drip irrigation system particularly for tillage, irrigation and weeding.
- **Increasing water productivity:** CA with drip irrigation has proven potential to increase the cycles of vegetable production through increased water productivity.

Some challenges were also observed when adopting CA with drip irrigation for smallholder farmers.

- Critics have highlighted that the uptake and success of CA by smallholders is frequently hindered by lack of labour availability, competing uses for crop residues and disappointing returns in yields. The latter is by protagonists then “blamed” on the only partial adoption of the CA principles.
- Competitive use of mulch; the mulch covers used were crop residues, dried grass, and other local organic materials which farmers also use it to feed their livestock.
- Water-lifting technique; the water-lifting technique used in Ethiopia, manual pulley system, was another challenge which required farmers to spend more time to extract water from groundwater wells to water storage tanks.
- It is suggested to test solar-driven pumps for irrigation which could potentially advance CA with drip irrigation production system. Also, intercropping forage in the rainfed corn production could be a potential solution to increase the availability of mulch in the dry season.

Overall benefits of conservation agriculture

- Conservation tillage systems are gaining increased attention as a way to reduce the water footprint of crops by improving soil water infiltration, increasing soil moisture and reducing runoff and water contamination.
- It improves soil fertility and yields.
- Promotes efficient water use.
- All with less inputs and which helps reduce the impacts of global warming and could prove to be a good adaptation strategy for climate change.
- Large scale adoption of CA could help reduce carbon emissions.

Constraints for adoption of conservation agriculture

Lack of appropriate seeders especially for small and medium scale farmers: Although significant efforts have been made in developing and promoting machinery for seeding wheat in no till systems, successful adoption will call for accelerated effort in developing, standardizing and promoting quality machinery aimed at a range of crop and cropping sequences. These would include the development of permanent bed and furrow planting systems and harvest operations to manage crop residues.

The wide spread use of crop residues for livestock feed and fuel: Specially under rainfed situations, farmers face a scarcity of crop residues due to less biomass production of different crops. There is competition between CA practice and livestock feeding for crop residue. This is a major constraint for promotion of CA under rainfed situations.

Burning of crop residues: For timely sowing of the next crop and without machinery for sowing under CA systems, farmers prefer to sow the crop in time by burning the residue. This has become a common feature in the rice-wheat system in north India. This creates environmental problems for the region.

Lack of knowledge about the potential of CA to agriculture leaders, extension agents and farmers: This implies that the whole range of practices in conservation agriculture, including planting and harvesting, water and nutrient management, diseases and pest control etc. need to be evolved, evaluated and matched in the context of new systems.

Skilled and scientific manpower: Managing conservation agriculture systems, will call for enhanced capacity of scientists to address problems from a systems perspective and to be able to work in close partnerships with farmers and other stakeholders. Strengthened knowledge and information sharing mechanisms are needed.

Conclusion

"Conserving resources-enhancing productivity" has to be the new mission: Conservation agriculture offers a new paradigm for agricultural research and development different from the conventional agriculture, aimed to achieve specific food grains production targets in India. It will enhance the capacity of scientists to address problems from a systems perspective; be able to work in close partnerships with farmers and other stakeholders and strengthened knowledge and information sharing mechanisms. Conservation agriculture offers an opportunity for arresting and reversing the downward spiral of resource degradation, decreasing cultivation costs and making agriculture more resource use-efficient, competitive and sustainable. Many of the innovative local and regional schemes in developing countries where techniques have been adopted to improve agricultural system sustainability have improved yield and yield stability, and thus often improved water productivity (Pretty *et al.*, 2006). This system had the advantage to preserve water and under the condition of a water deficit during the vegetation period, it contributes to a more efficient use of fertilizers (Mircea *et al*., 2012). Encouragingly, there is currently exciting progress in improving crop production and water productivity through conservation agriculture.

Reference

1. Ahmad M, Giordano M, Turral H, Masih I, Masood Z. At what scale does water saving really save water. Journal of Soil and Water Conservation. 2007; 62:29-37.
2. Behera UK, Amgain LP, Sharma AR. Conservation agriculture: principles, practices and environmental benefits. In Behera UK, Das TK and Sharma AR (Eds.), Conservation Agriculture. Division of Agronomy, Indian Agricultural Research Institute, New Delhi – 110012, 2010, 28-41, 216.
3. Bezborodov G, Shadmanov A, Mirhashimov DK, Yuldashev RT, Qureshi T, Noble AS. Mulching and water quality effects on soil salinity and sodicity dynamics and cotton productivity in Central Asia. Agriculture, Ecosystems and Environment. 2010; 138:95-102.
4. Bhatt R, Khera KL. Effect of tillage and mode of straw mulch application on soil erosion losses in the submontaneous tract of Punjab, India. Soil and Tillage Research. 2006; 88:107-115.
5. De Vita P, Di Paolo E, Fecondo G, Di Fonzo N, Pisante M. No-tillage and conventional tillage effects on durum wheat yield, grain quality and soil moisture content in Southern Italy. Soil and Tillage Research. 2007; 92:69-78.
6. Derpsch R. No-tillage and conservation agriculture: a progress report. In: Goddard T *et al*., editors, No-till farming systems. World Association of Soil and Water Conservation, Bangkok. 2008; 3:7-39.
7. Dumanski J, Peiretti R, Benetis J, McGarry D, Pieri C. The paradigm of conservation tillage. Proceedings of World Association of Soil and Water Conservation. 2006; 1:58-64.
8. FAO. FAOSTAT database: agriculture production. Food and Agriculture Organization of the United Nations, Rome, 2013.
9. Food and Agriculture Organization of the United Nations (FAO), 2015. Available online at http://www.fao.org/ag/ca/6c.html.
10. Ghosh PK, Das A, Saha R, Kharkrang E, Tripathy AK, Munda GC, Ngachan SV. Conservation agriculture towards achieving food security in north east India. Current Science. 2010; 99(7):915-921.

11. Gregory PJ. Agronomic approaches to increasing water use efficiency. In: Bacon MA editor. Water use efficiency in plant biology. Blackwell Publishing; Oxford, UK. 2004; 6:142-170.

12. Gupta R, Seth A. A review of resource conservation technologies for sustainable management of the rice-wheat cropping system of the Indo-Gangetic plains. Crop Protection. 2007; 26(3):436-447.

13. Hobbs PR, Gupta RK. Rice-wheat cropping systems in the Indo-Gangetic plains: Issues of water productivity in relation to new resource conservation technologies. In Water Productivity in Agriculture: Limits and Opportunity for Improvement Ed. Kijne JW, Barker R, Molden D, CABI Publication and IWMI, 2003.

14. Hobbs PR, Sayre K, Gupta R. The role of conservation agriculture in sustainable agriculture. Philos Trans R Soc B. 2008; 363:543-555.

15. Rockstroma J, Kaumbutho P, Mwalley J, Nzabi AW, Temesgen M, Mawenya L *et al*. Conservation farming strategies in East and Southern Africa: Yields and rain water productivity from on-farm action research. Soil and Tillage Research. 2009; 103:23-32.

16. Jat ML, Gathala MK, Ladha JK, Saharawat YS, Jat AS, Kumar V *et al*. Evaluation of precision land leveling and double zero-till systems in the rice-wheat rotation: water use, productivity, profitability and soil physical properties. Soil and Tillage Research. 2009; 105:112-121.

17. Kahlown MA, Azam M, Kemper WD. Soil management strategies for rice-wheat rotations in Pakistan's Punjab. Journal of Soil and water Conservation. 2006; 61(1):40-44.

18. Kassam A, Friedrich T, Shaxson F, Pretty J. The spread of conservation agriculture: justification, sustainability and uptake. Int. J Agric. Sustain. 2009; 7(4):292-300.

19. Kassam AH, Friedrich T. Perspectives on Nutrient Management in Conservation Agriculture. Invited paper, IV World Congress on Conservation Agriculture, New Delhi, India, 2009, 4-7.

20. Kijne J, Barker R, Molden D. Water productivity and Agriculture; limits and opportunities for improvement CABI Press, Wallingford, U.K., 2003.

21. Kukal SS, Singh Y, Jat ML, Sidhu HS. Improving water productivity of wheat-based cropping systems in South Asia for sustained productivity. Advances in Agronomy. 2014; 127:159-230.

22. Kumar MD, Singh OP, Samad M, Turral H, Purohit C. Water productivity of irrigated agriculture in India: Potential areas for improvement. Ibid, 2008, 121-140.

23. Kumari Namrata, Ravish Chandra. Estimation of water productivity of different varieties of rice in Burhi Gandak basin of north Bihar. Journal of Pharmacognosy and Phytochemistry. 2019; 8(1):2631-2634.

24. Lal R. Climate-resilient agriculture and soil Organic Carbon. Indian Journal of Agronomy. 2013; 58(4):440-450.

25. Mircea Adrian Grigoras, Agatha Popescu, Doru Pamfil, Ioan Has, Mihai Gidea. Conservation Agriculture versus Conventional Agriculture: The Influence of Agriculture System, Fertilization and Plant Protection on Wheat Yield. Not Bot Horti Agrobo. 2012; 40(1):188-194.

26. Molden D. Accounting for water use and productivity. SWIM paper 1. International water Management Institute, Colombo, Sri Lanka, 1997.

27. Molden D, Sakthivadivel R. Water accounting to excess use and productivity of water. Water resources Development. 1999; 15:55-71.

28. Najafi P, Tabatabaei SH. Effect of using subsurface drip irrigation and ET-HS model to increase WUE in irrigation of some crops. Irrig. Drain. 2007; 56:477-486.

29. Palada M, Bhattarai S, Wu DL, Roberts M, Bhattarai M, Kimsan R *et al*. More crop per drop: using simple drip irrigation systems for small-scale vegetable production. AVRDC-The World Vegetable Center, Shanhua, Taiwan, 2011, 83.

30. Pretty JN, Noble AD, Bossio D, Dixon J, Hine RE, Penning De Vries FW *et al*. Resource-conserving agriculture increases yields in developing countries. Environ Sci Technol. 2006; 40(4):1114-9.

31. Rockstro J. Water for food and nature in drought-prone tropics: vapour shift in rain-fed agriculture. Royal Society Transactions B: Biological Sciences, 2003, 358.

32. Silici L. Conservation agriculture and sustainable crop intensification in Lesotho, Food and Agriculture Organization of the United Nations, Rome, 2010, 61.

33. Singh B, Humphreys E, Eberbach PL, Katupitiya A, Singh Y, Kukal SS. Growth, yield and water productivity of zero till wheat as affected by rice straw mulch and irrigation schedule. Field Crop Research. 2011; 121:209-225.

34. Tewodros Assefa, Manoj Jha, Manuel Reyes, Seifu Tilahun, Abeyou W Worqlul. Experimental Evaluation of Conservation Agriculture with Drip Irrigation for Water Productivity in Sub-Saharan Africa. Water. 2019; 11:530.

35. Thiombano L, Meshack M. Scaling-up conservation agriculture in Africa: strategy and approaches, Food and Agriculture Organization of the United Nations, Sub-Regional Office for Eastern Africa, Addis Ababa, 2009, 31.

36. Wallace JS, Gregory PJ. Water resources and their use in food production systems. Aquat. Sci. 2002; 64:363-375.

37. Wang CR, Tian XH, Li SX. Effects of plastic sheet-mulching on ridge for rainwater-harvesting cultivation on WUE and yield of winter wheat. Sci. Agric. Sin. 2004; 37:208-214.

38. Wassmann R, Jagadish SVK, Sumfleth K, Pathak H, Howell G, Ismail A *et al*. Regional vulnerability of climate change impacts on Asian rice production and scope for adaptation. Advances in Agronomy. 2009; 102:91-133.

39. Zhang S, Sadras VO, Chen X, Zhang F. Water use efficiency of dryland wheat in the Loess Plateau in response to soil and crop management. Field Crops Res. 2013; 151:9-18.

Chapter - 2
Water Dynamics in the Soil-Plant-Atmosphere System

Authors

Meenakshi Attri
Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology-Jammu, Main Campus, Chatha, Jammu & Kashmir, India

Qurat-ul-ain aga
Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology-Kashmir, Main Campus, Chatha, Jammu & Kashmir, India

Jyoti Sharma
Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology-Jammu, Main Campus, Chatha, Jammu & Kashmir, India

Chapter - 2

Water Dynamics in the Soil-Plant-Atmosphere System

Meenakshi Attri, Qurat-ul-ain aga and Jyoti Sharma

Abstract

The water problem in agriculture is related both to weather and to the reserves of water in the soil that are available to plants. Water dynamics in the soil-plant atmosphere system concerns the capacity of the soil water reservoir, its depletion and replenishment and its efficient management for crop production. The concept of the soil as a reservoir for water is appealing and useful. Since only a small amount of water can be stored in crop plants relative to the rate of transpiration through them, it is the storage of water within the soil pores that permits transpiration to continue for several days without recharge by rainfall or irrigation. However, water storage in the soil is not similar to that in a bucket. Some water may drain out of the root zone, and not all water remaining in a drying soft can be taken up by the plant as rapidly as it is needed because it is held too tightly by soil particles. Although methods of determining the capacity of the soil water reservoir available to the plant are not exact, the concept permits calculations of the soil water balance and its impact on crop production. Water-balance calculations using computers are becoming more common. There should be more emphasis on water-balance technology in the future because it is needed for accurate estimation of crop yields, early warning about food shortages, better farm management, reliable irrigation scheduling and water-resource planning, etc. Because of these urgent needs, it is important to develop models of the water balance that are as general as possible so that local calibrations are eliminated or at least minimized. Models should also not depend on the input of weather records that are difficult to obtain.

Keywords: Fresh water, glaciers, hydrological cycle, water resources, transpiration

Introduction

For the development, production, progress and environmental balance within watersheds, we need to know more about water resources of a region as the water is a very vital component for the survival of human being's animals and plant. The world's total water resources are estimated at 1.36 x 108 M ha-m. Of these global water resources about 97.2% is salt water mainly in oceans and only 2.8% is available as fresh water at any time on planet earth. Out of this 2.8% of fresh water, about 2.2% is available as surface water and 0.6% as ground water. Even out of this 2.2% of surface water, 2.15% is fresh water in glaciers and ice caps and only of the order of 0.01% is available in lakes and streams; the remaining 0.04% is being in the other forms of hydrological cycle. Out of 0.6% of stored ground water, only about 0.25% can be economically extracted with the present drilling technology (the remaining being at greater depths and is non-extractable). If we take this circulating water (0.04%) only, evaporation from ocean is about 82.1 percent of total circulating water and evaporation from soils, lakes, streams, etc. is about 17.9% of total circulating water.

Out of 82.1 percent, only about 7.1 percent of total circulating water comes from oceans. Thus about only 25 percent (17.9+7.1 percent) of circulating water falls on land surface so it is essentials to study the hydrological cycle as it helps us to understand the amount of water available to crops during the various parts of the year, the effect of water on soil and plant, amount of water available for industry and for daily use by human, animals and other living materials. Since only 0.01% water is available on the earth surface and that too 70% of it falls during three to four months of monsoon season and remaining is distributed over 8-9 months, furthermore some part of the world are getting rains whereas other parts are totally dry simply employees that the distribution of water is not uniform in space and with respect to time, hence there is a need to study the subject water management.

Per capita water availability in our country is decreasing day by day. It was more than 5300 m3 in 1951. But decreased to 1905 m3 in 1999 and is likely to be less than 1500 m3 by 2025. Per capita availability of water less than 1700 m3 is considered as a stress level. Share of water use other than for agriculture was only 13% in 1985, which is likely to become 27% by 2025. Such a fast growth of water need in the face of emerging supply constraints is likely to result in a wide supply gap for irrigation water in near future. Scope of expanding water supplies through development of new water resources is limited as

- Suitable sites are fewer.
- Development costs are too high.
- Environmental concerns are too strong.

The crisis about water resources development and management thus arises due to limited availability of water at the actual place of utilization, as water is very unevenly distributed over place and time, stressing its random and stochastic characteristics.

Why water is scare:

- Increase in water requirements due to increase in population.
- Easily available sources of water tapped already.
- Contamination of available water sources due to increase in human activities.
- Industrial development.
- Human needs and desire for higher standards of living.
- Delay in project initiation due to increasing social and environmental concerns.

Tips for water conservation

Agricultural Fields:

Do’s:

- Learn to compute water requirement of crops.
- Apply as much water as needed.
- Vary water application rates with growth of crop.
- Choose irrigation system best suiting to crops, soil and climate.
- Use sensor to indicate irrigation time.
- Recycle tail end water for irrigation.
- Level the land properly.
- Check joints, coupling properly for leaks etc.
- Provide a good maintenance to irrigation system.
- Packs the holes properly for leaks etc.
- Maintain a record of canal flow.
- Use clean water with drip and sprinkler system.

Do not:

- Do not over irrigate the crop.
- Do not irrigate the fields frequently rather follow a proper schedule.
- Do not allow weeds to grow as they will compete for water needs with the crop.

- Do not use leaking/cut outs pipes for irrigate.
- Do not use wild guess in field irrigation time.

Do not consider water as priceless resource think if no water then what and how?

Role of water

Water is equally important for plants. It performs the following important functions in plants:

1) Water is essential for the germination of seeds and growth of plants.
2) During the process of photosynthesis, plants synthesize carbohydrates from carbon dioxide and water. Therefore, water is one of the essential components for the plant.
3) Water acts as a solvent for fertilizers and other minerals, which are taken up by the plant roots in the form of solution. Thus, water serves as the medium in which plants absorb soluble nutrients from the soil.
4) Water serves as medium for transport of chemicals to and from cells.
5) Water pressure in plant cells provides the firmness to the plants.
6) Aquatic life is possible in water only.
7) Water is involved in hydrolysis of starch to sugar.
8) Water is an important constituent of plant forming more than 80% in herbaceous plants and over 50% in woody plants.8. water is a constituent of protoplasm.
9) Water maintain turgidity of cells which is essential for stomatal opening.

Plant structure

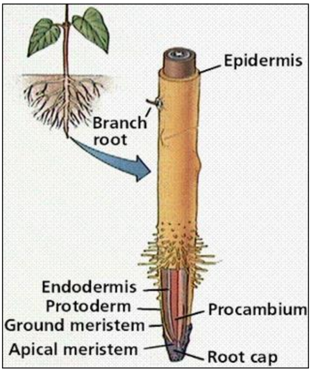
A plant has two organ systems:

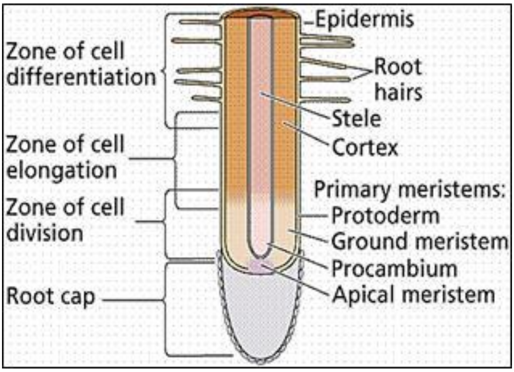
1) The shoot system
2) **The root system:** The shoot system is above ground and includes the organs such as leaves, buds, stems, flowers (if the plant has any) and fruits (if the plant has any). The root system includes those parts of the plant below ground, such as the roots, tubers, and rhizomes.

Plant cells are formed at meristems and then develop into cell types which are grouped into tissues. Plants have only three tissue types:

1) Dermal
2) Ground
3) Vascular

- Dermal tissue covers the outer surface of herbaceous plants. Dermal tissue is composed of epidermal cells, closely packed cells that secrete a waxy cuticle that aids in the prevention of water loss.
- The ground tissue comprises the bulk of the primary plant body. Parenchyma, collenchyma and sclerenchyma cells are common in the ground tissue.
- Vascular tissue transports food, water, hormones and minerals within the plant. Vascular tissue includes xylem, phloem, parenchyma and cambium cells.





Structure of root **Structure of meristem**

Plant cell types rise by mitosis from a meristem. A meristem may be defined as a region of localized mitosis. Meristems may be at the tip of the shoot or root (a type known as the apical meristem) or lateral, occurring in cylinders extending nearly the length of the plant. A cambium is a lateral meristem that produces (usually) secondary growth. Secondary growth produces both wood and cork (although from separate secondary meristems).

Parenchyma

- A generalized plant cell type, parenchyma cells are alive at maturity. They function in storage, photosynthesis and as the bulk of ground and vascular tissues. Palisade parenchyma cells are elongated cells located in many leaves just below the epidermal tissue. Spongy mesophyll cells occur below the one or two layers of palisade cells. Ray parenchyma cells occur in wood rays, the structures that transport materials laterally within a woody stem. Parenchyma cells also occur within the xylem and phloem of vascular bundles. The largest parenchyma cells occur in the pith region, often, as in corn (*Zea*) stems, being larger than the vascular bundles. In many prepared slides they stain green.

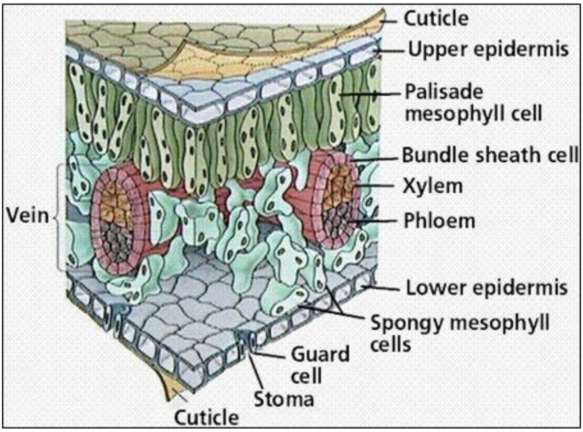
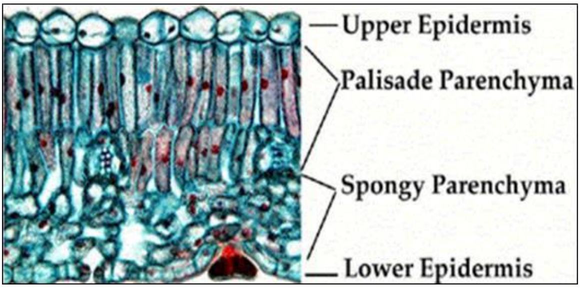
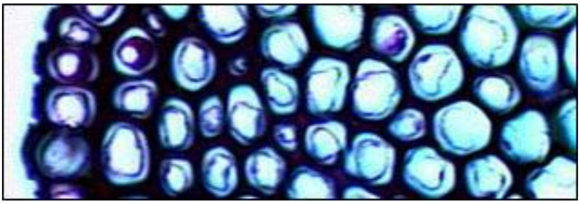


Diagram of leaf structure and the arrangement of tissue layers within the leaf

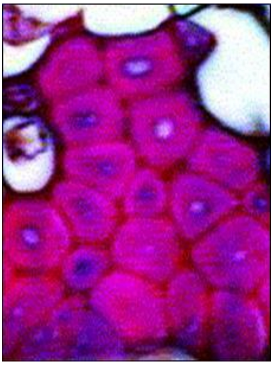


- *Collenchyma* cells support the plant. These cells are characterized by thickenings of the wall, the are alive at maturity. They tend to occur as part of vascular bundles or on the corners of angular stems. In many prepared slides they stain red.



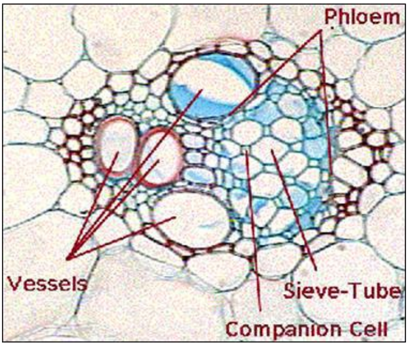
Thick walls on the collenchyma cells

- *Sclerenchyma* cells support the plant. They often occur as bundle cap fibers. Sclerenchyma cells are characterized by thickenings in their secondary walls. They are dead at maturity. They, like collenchyma, stain red in many commonly used prepared slides.



A common type of schlerenchyma cell is the fiber.

- *Xylem* is a term applied to woody (lignin-impregnated) walls of certain cells of plants. Xylem cells tend to conduct water and minerals from roots to leaves. While parenchyma cells do occur within what is commonly termed the "xylem" the more identifiable cells, tracheids and vessel elements, tend to stain red with Safranin-O. Tracheids are the more primitive of the two cell types, occurring in the earliest vascular plants. Tracheids are long and tapered, with angled end-plates that connect cell to cell. Vessel elements are shorter, much wider and lack end plates. They occur only in angiosperms, the most recently evolved large group of plants.



Tracheids, longer and narrower than most vessels, appear first in the fossil record. Vessels occur later. Tracheids have obliquely-angled endwalls cut across by bars. The evolutionary trend in vessels is for shorter cells, with no bars on the end walls.

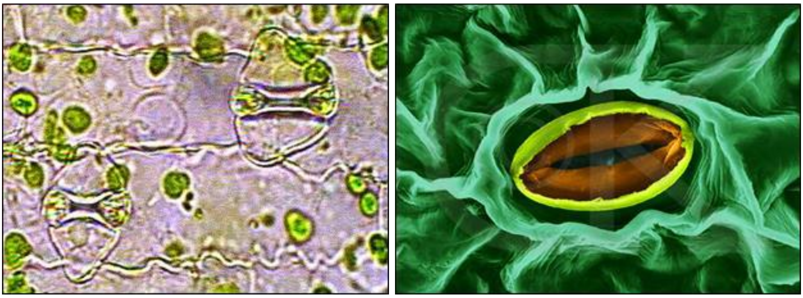
- *Phloem* cells conduct food from leaves to rest of the plant. They are alive at maturity and tend to stain green (with the stain fast green). Phloem cells are usually located outside the xylem. The two most common cells in the phloem are the companion cells and sieve cells. Companion cells retain their nucleus and control the adjacent sieve cells. Dissolved food, as sucrose, flows through the sieve cells.

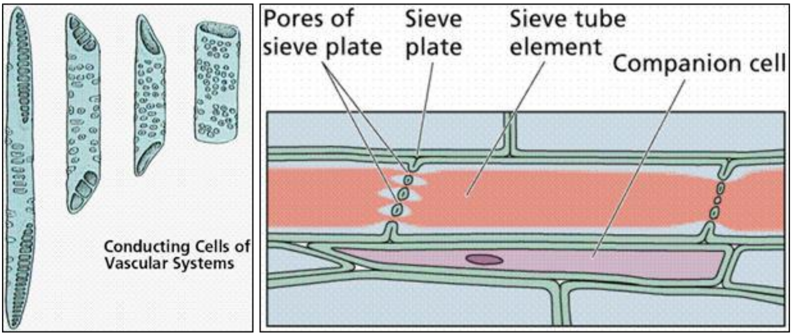
Epidermis

- The epidermal tissue functions in prevention of water loss and acts as a barrier to fungi and other invaders. Thus, epidermal cells are closely packed, with little intercellular space. To further cut down on water loss, many plants have a waxy cuticle layer deposited on top of the epidermal cells.

Guard cells

To facilitate gas exchange between the inner parts of leaves, stems, and fruits, plants have a series of openings known as stomata (singular stoma). Obviously, these openings would allow gas exchange, but at a cost of water loss. Guard cells are bean-shaped cells covering the stomata opening. They regulate exchange of water vapor, oxygen and carbon dioxide through the stoma.





Phloem cells as seen in longitudinal section

Plant structure: Absorption of water and nutrients is the main function of roots of almost all plant species. Young roots of plants are the most important for water absorption even though old and suberised roots also absorb water. A young active root has upper epidermis, thick layer of cortex and finally the centrally located vascular system. When Yong, these cells produce roots hairs which facilitate larger surface area for higher water and nutrient absorption. Cortex is made up of mainly parenchymatous cells with large air spaces between the cells. The vascular bundles has at its peripheral layer a meristematic cell layer called the pericycle which produces most of root branching. Within the vascular bundles are the phloem tubes near the pericycle and xylem tubes near the core or the centre of the root. The xylem vessels convey the water and nutrient absorbed by the roots to the stem.

The root tip has the root cap which protects the growing meristematic tissues. Behind the root cap, is the zone of root cell elongation where faster water uptake takes place. Water is absorbed by epidermal cells, root hairs and pass through cortex and enter xylem vessels. Water moves up in the xylem vessels of stem and supplies water to leaves and other plant parts. water saturates all the cells of leaf and escape through stomata and cuticle, which is known as transpiration.

Plant water status: Water deficits reduce turgidity which in turn affects cell expansion. Cell division, photosynthesis etc., It is often essential to measure water status of plants which is expressed both as water content and energy status of water. Relative water content is the ratio of actual water content to water content at saturation and is generally expressed as percentage. Actual water content is obtaine by deducting dry weight of sample (DW) from fresh weight of sample (FW). While water content at saturation is the difference between saturation weight or turgid weight (TW) and dry weight.

$$RWC = \frac{FW\_ DW}{TW\ \_- DW} X\ 100$$

Energy status of water in plants indicates the case with which water is available to plant cells. Higher the water potential of plants easier the availability of water to plant cells. Water potential in a plant tissues is always less than zero. Hence negative no. Water potential of plants leaves is likely to be in the range of -0.2 to -0.8 when plants are in the soil with sufficient moisture. Water potential is measured with thermocouple psychrometer or pressure chamber.

The indirect method of estimating plant water status are by measuring leaf temperature, canopy temperature, canopy air temperature differentials, diffusion resistance and transpiration rate. Leaf temperature rises due to absorption of solar radiations which is later reduced by the cooling effect of transpiration. Temperature of leaves of stressed plants is high due to decreased transpiration. Whereas temperature of leaves of well-watered plants is low as transpiration is normal. Leaf temperature can be measured with thermocouple IR thermometer.

Plant water terminology

Plant water potential

Energy status of water in plant cell is determined by three major factors: Turgor pressure(P), Imbibitional pressure (m) and solute or osmotic pressure (s). Pressure arising both from gravitational force and intercellular pressure can be included in the turgor pressure term. Total potential of water in plants can be expressed as indicated below:

- &= &p+&m+&s

Where,

& = Total water potential.

&p = Turgor potential (equivalent to pressure potential in soil).

&m = Imbibitional potential (equivalent to matric potential in soil).

&s = Solute or osmotic potential.

Plant water potential increases with added pressure (turgor) and decrease with increase in osmotic pressure. In the past, the condition of water in plant used to be expressed in terms of its diffusion pressure deficit (DPD) OR equivalent term such as suction force.

DPD = -TP + IP+ OP

Where,

DPD = Diffusion pressure deficit.

TP = Turgor pressure.

IP = Imbibitional pressure.

OP = Osmotic or solute pressure.

Value of OP are considered to be always positive(+),value of TP and IP are also considered positive(+),

DPD of pure water at the reference is taken zero, thus DPD values in plant system are always positive and water will tend to move from a point of low DPD to one of high DPD.

Turgor pressure potential = +10 bars

Imbibitional potential = -1 bars

Solute or osmotic potential= -18 bars

Total water potential = -9 bars

If the cells are placed in pure water (&=0). Water will move into the cells {high to low potential). Similarly water moves from cell where &= -9bars to one where &= -12 bars.

Magnitude of after potential in SPAC

Components	**Water Potential**
Soil	-0.1 to -20
Leaf	-5.0 to -50
Atmosphere	-1000 to -2000

Plant characteristics

Root penetration is seriously affected by a hard pan or compacted layer in the soil profile. In a shallow soil, roots may be continued to a thin layer of soil irrespective of their usual pattern. Similarly, high ware table limits normal root growth. Crops with extensive and dense roots can utilize soil moisture than crops with sparse and shallow roots.

Rooting depth of annual field crops on deep well drained soils range from 0.30 to 2.0m. In general, the root zone depth of crops on clayey soils is reduced by 25 to 35 percent and on sandy soils increased by 25 to 35 percent.

Shallow		Medium		Deep	
Rice	0.5-0.6	Barley	1.0-1.5	Cotton	1.0-1.7
Onion	0.3-0.5	Wheat	0.8-1.5	Maize	1.0-1.6
Cabbage	0.4-0.5	Castor	0.9-1.2	Sorghum	1.0-2.0
Cauliflower	0.3-0.5	Tobacco	0.7-1.0	Pearl Millet	1.0-1.7
Potatoes	0.4-0.6	chillies	0.6-0.9	Sugarcane	1.0-2.0
		Peas	0.6-1.0	Soyabean	1.0-1.5
		tomatoes	0.7-1.5		

Rooting depths (m) of annual field crops on deep well drained soils

The soil depth from which the stop extract most of the water needed to meet its evapotranspiration requirement is known as effective root zone depth. It is also called as design moisture extraction depth, the soil depth used to determine irrigation water requirement fir design. It is the soil depth in which optimum available SM level must be maintained for higher productivity of crops.

Moisture extraction pattern

Moisture extraction pattern shoes about 40% of the extracted moisture comes from upper quarter of the root zone, 30% 30% from second quarter, 20% from third quarter and 10% from fourth bottom quarter. This general pattern of extraction slightly varies with irrigation frequency. Higher the frequency, greater the moisture extraction from first quarter of the root zone. Low frequency of irrigation leading to depletion of soil moisture thus resulting in more moisture extraction from lower quarters of the root zone soil depth.

Moisture sensitive periods: Optimal soil koisture for plant growth varies with the stage of crop growth. Certain periods during the crop growth and development are most sensitive to soil moisture stress compared with others. These periods are known as moisture sensitive periods. The term critical period is commonly used to describe the stages of growth when plants are most sensitive to shortage of water.

Moisture sensitive (critical) periods of crops indicate necessity for adequate available soil koisture during reproductive stages of crops. Water shortage during germination and emergence affect stand establishment. Moisture stress at heading and flowering stages reduces grain formation while that during grain development leads to shrieveled grains with low test weight.

For realizing maximum benefits from the scarce irrigation water irritation are to be scheduled at moisture sensitive periods by with holding irrigations at other periods of lesser sensitivity. Such irrigation schedules along with improved management practices increases the water use efficiency in crop production.

Moisture sensitive stages: Visible stages of crop growth are Germination, Emergence, vegetative growth, Flowering, Grain formation or fruiting & grain maturation.

Panicle initiation in Cereals & Millets is the most important stage. The term critical periods is most commonly used to define the stage of growth when the plants are most sensitive to moisture conditions than at other stages of depth. A restricted water supply during the moisture sensitive stages will irrevocably reduce the yield & the provision of water or fertilizer at other growth stages will not effect the loss of water or fertilizer at other growth stages in yield.

Crop	**Moisture sensitive periods**
rice	Panicle initiation, heading & flowering
Sorghum	Booting, flowering, milky & dough stages
Maize	Tasseling. Silking & early grain formation
Pearl Millet	Heading & flowering
Finger Millet	Panicle initiation & flowering
Wheat	CRI, Shooting & heading
Barley	End of shooting, Heading
Groundnut	Rapid flowering, Peg penetration, & early pod development
Sesamum	Flowering to maturity
Sunflower	Flower bud initiation. Head initiation, Flowering
Safflower	From Rossette to Flowering
Soyabean	Flowering & Seed formation
Cotton	Flowering & ball development
Sugarcane	Formative phase particularly during tillering
Tobacco	Entire growth period
Chillies	Flowering
Potato	Tuber formation to Tuber maturity
Onion	Bulb formation to maturity
Peas	Flowering& Pod development
Cabbage	Head initiation until becoming firm
Tomato	From the commencement of fruit set
Carrot	When root enlargement starts
Citrus	Flowering, fruit setting, Fruit growth
Banana	Early vegetative period, Flowering & yield formation

Crops should not experience any moisture stress during moisture sensitive stages. To obtain maximum possible yield of crops from a limited quantity of water, irrigation has to be scheduled at those stages when most beneficial response is obtained &water withheld to the extent possible at other stages of growth.

Water shortage during vegetative stage usually has little effect on subsequent production unless it is severe to drastically reduce leaf area. Moisture stress during Heading & Flowering reduces grain formation. Moisture stress during grain development cause shrivelled grains.

Cereals show a marked sensitivity to moisture stress during the formation of reproductive organs & Flowering stages.

Stages of growth	**Yield (% over control)**
Early Tillering	75
Active Tillering	84
Late Tillering	88
Spikelet differentiation	80
Reduction division	30
Early Heading	36
Late Heading	74
Grain Ripening	90

In dwarf varieties of wheat, crown root initiation is a moisture sensitive stages. The internodes of stem just below the soil is termed as crown & the new roots & Tillers are initiated from this region. Crown roots are formed at about 18-20 ays after Planting wheat in South India.

Tillering is a yield contributing character &moisture stress at the crown root initiation stage reduces yield drastically.

Sufficient supply of water upto Flowering increases vegetative growth of Leg’s but not yield. Leg’s are particularly sensitive to soil moisture conditions during Flowering and Pod development. Irrigation at start of flowering increases as the no. of seeds/pod while Irrigation at pod growth increases the test weight.

For Perrenial crops, all developments stages are critical periods to certain extent. The activities of the plant within each growth stage are not independent of previous stage. Total growth and yield of perennial plants is summation of effects of SM at each growth stage. But adequate irrigation is essential at critical periods such as flower bud initiation and formation, Flowering and Fruit set. Mango and Citrus are exception where flower bud formation increases when water supply is restricted prior to flower bud initiation. Proper moisture supply during fruit set and enlargement is essential. Perennial crops are sensitive to water supply during pod development of maximum vegetative growth. Adequate water supply is necessary at all stages to maintain effective and healthy foliage which can utilize incoming energy. Response of yield to water supply is quantified through yield response factor (ky) which related relative yield decrease to relative ET deficit.

$$KY = \frac{1-(Ya/Yb)}{1-(Eta/ETm)}$$

Where,

Ya - Actual yield(kg/ha)

Ym = Maximum possible yet under unlimited water supply

Eta = Actual ET

ETm = Maximum ET

Higher values indicate more response to water or higher sensitivity to ewater deficit.

Yield response factor for important crops for different growth stages is given below.

Crop	**Crop Growth Period**			
Crop	**Vegetative**	**Flowering**	**Yield forum**	**Ripening**
Wheat	0.2	0.6	0.5	-
Cotton	0.2	0.5	-	0.25
Groundnut	0.2	0.8	0.6	0.20
Sugarcane	0.2	0.55	0.45	0.2
Tomato	0.75	-	0.50	0.10
	0.40	1.1	0.80	0.4

Conclusion

Although precise definitions of the two concepts for the upper and lower limits of soil water availability are limited by the dynamics of the soil-plant-atmosphere system, the use of these rough limits helps greatly in evaluating the impact of soil water balance on crop production. Estimates of extractable water determined in the field overcome several problems associated with definitions of the upper and lower limit and provide a measure of the soil water reservoir which is useful in estimating the influence of soil water deficits on important processes coupled with plant growth and yield. Physical measurements such as stomatal conductance and water potential, while they are sensitive to plant water deficits, have proven to be of limited value in operational use because they lack sensitivity under marginal conditions of stress when some growth processes are restricted. Much is yet to be learned about the dynamics of water in the soil-plant atmosphere system. A specific strategy to guide research to meet future production demands requires close linkage between scientists of several disciplines, especially plant breeding, plant physiology, climatology, and soil and crop management. Multidisciplinary teams will be required to meet the challenge of the future to produce optimum crop production systems that avoid or tolerate plant water stress.

References

1. Sgherri C, Kadlecová Z, Pardossi A, Navari-Izzo F, Izzo R. Irrigation with diluted seawater improves the nutritional value of cherry tomatoes. Journal of Agricultural Food Chemistry. 2008; 56:3391-3397.
2. Rameshwaran P, Tepe A, Yazar A, Ragab R. Effects of drip-irrigation regimes with saline water on pepper productivity and soil salinity under greenhouse conditions. Science Horticulture. 2016; 199:114-123.
3. Sakamoto K, Kogi M, Yanagisawa T. Effects of salinity and nutrients in seawater on hydroponic culture of red leaf lettuce. Environmental Control Biology. 2014; 52:189-195.
4. Pascale SD, Maggio A, Fogliano V, Ambrosino P, Ritieni A. Irrigation with saline water improves carotenoids content and antioxidant activity of tomato. Journal of horticultural sciences Biotechnology. 2001; 76:447-453.
5. Shannon M, Grieve C. Tolerance of vegetable crops to salinity. Science Horticulture. 1998; 78:5-38.
6. Magán J, Casas E, Gallardo M, Thompson R, Lorenzo P. Uptake concentrations of a tomato crop in different salinity conditions. In Proceedings of the International Symposium on Soilless Culture and Hydroponics 697, Leuven, Belgium, 2004, 365-369.
7. White PJ, Broadley MR. Biofortification of crops with seven mineral elements often lacking in human diets-iron, zinc, copper, calcium, magnesium, selenium and iodine. New Phytology. 2009; 182:49-84.
8. Gardiner D. Crop production in saline environments: Global and integrative perspectives. Horticulture Sciences. 2003; 38:14-57.

9. Sgherri C, Kadlecová Z, Pardossi A, Navari-Izzo F, Izzo R. Irrigation with diluted seawater improves the nutritional value of cherry tomatoes. Journal of Agriculture Food chemistry. 2008; 56:3391-3397.
10. Rameshwaran P, Tepe A, Yazar A, Ragab R. Effects of drip-irrigation regimes with saline water on pepper productivity and soil salinity under greenhouse conditions. Science Horticulture. 2016; 199:114-123.

Chapter - 3
Climate Smart Agricultural Practices for Sustainable Crop Production

Authors

Jyoti Sharma
Division of Agronomy, Sher-e-Kashmir University of Agricultural Science and Technology of Jammu, Jammu and Kashmir, India

Monika Menia
Division of Agronomy, Sher-e-Kashmir University of Agricultural Science and Technology of Jammu, Jammu and Kashmir, India

Meenakshi Attri
Division of Agronomy, Sher-e-Kashmir University of Agricultural Science and Technology of Jammu, Jammu and Kashmir, India

Tamana Sharma
Division of Soil Science and Agricultural Chemistry, Sher-e-Kashmir University of Agricultural Science and Technology of Jammu, Jammu and Kashmir, India

Chapter - 3

Climate Smart Agricultural Practices for Sustainable Crop Production

Jyoti Sharma, Monika Menia, Meenakshi Attri and Tamana Sharma

Abstract

Between now and 2050, global food production needs to increase by 60% to feed the world's expected population of 9.6 billion (FAO, 2013). The fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC, 2007) confirms that the global average temperature has increased by 0.740C over the last 100 years and the projected rise in warming by 2100 is about 1.8-40C. Global warming and the resultant climate change is expected to increase the occurrences and intensity of extreme weather events, such as floods, droughts and severe cyclonic storms (Dhanya and Ramachandran, 2016). This will exert intense pressure on agro-ecosystems that are already overburdened, particularly in developing countries as most of those increases in production have to occur in this part of the world. The agricultural production system could be further worsened by climate change through increasing water scarcity, frequency and severity of floods and declining soil carbon (Geethalakshmi *et al.*, 2009). These changes would further increase the pressure on agriculture, as it has to meet the increasing demand for food grains to be produced from the same or even shrinking cultivable land (Aggarwal, 2008). A Climate Smart Agriculture (CSA) approach tries to integrate climate change into planning and implementation of sustainable agricultural practices so as to increase the resilience of agriculture to climate variability through better adaptation to climate change and reduce agriculture's contribution to global warming (Lipper *et al.,* 2014). Use of high-yielding and stress-tolerant varieties/breeds, and the adoption of improved management practices increases farm production even under adverse climatic conditions. Increased farm production and income enhance farmers' capacity to cope with weather extremes (Raza *et al.,* 2019). Similarly, agricultural practices such as minimum tillage, residue management, and precision nutrient management increase resource-use efficiency, thereby reducing greenhouse gas (GHG) emissions without

compromising yield and contributing to sequestering atmospheric carbon into agro-ecosystems. All these practices with 'triple wins' without regrets, losers, and trade-offs are termed 'CSA'. CSA refers to packages of technologies/agricultural practices that addresses food security and climate challenges by sustainably increasing agricultural productivity and income, adapting and building resilience to climate change, and reducing and/or removing GHG emission, where possible (Dinesh *et al.*, 2015). At field level, a wide range of agricultural practices and approaches that are currently available can contribute to increased production as well as environmental sustainability. The CSA At field level, a wide range of agricultural practices and approaches that are currently available can contribute to increased production as well as environmental sustainability. The CSA includes several portfolios of interventions such as water-smart agricultural practices (rainwater harvesting, laser land levelling, micro-irrigation, raised bed planting, crop diversification, alternate wetting and drying in rice and direct seeded rice), weather-smart activities (ICT-based agro-met services, index-based insurance, stress-tolerant crops and varieties), nutrient-smart practices (precision fertilizer application using Nutrient Expert decision support tools, Green Seeker and Leaf Color Chart, residue management, legume catch-cropping), carbon and energy-smart (zero tillage, residue management, legumes) and knowledge-smart activities (farmer-farmer learning, capacity enhancement on climate-smart agriculture, community seed banks and cooperatives) (Aggarwal *et al.*, 2013). Many of these practices have been proved to be resilient to climatic extremes, productive and have low environmental footprints (Aryal *et al.*, 2016).

Keywords: Climate smart agriculture, resource conservation, nutrient use efficiency, minimum tillage, environment sustainability

Introduction

Climate is an important biophysical factor influencing the growth, development and productivity of crops. Seasonal climate variability and increase in frequency and intensity of extreme weather events are important environmental threats of the 21st century. Climate change is often used interchangeably with global warming. Climate change is a significant change in temperature, precipitation, or wind lasting for an extended period (decades or longer) and it is caused by both natural and anthropogenic factors. The effect of anthropogenic factors like increase in global atmospheric temperature and carbon dioxide (CO_2) levels over the long-term average are important indicators of climate change. The global mean temperature has increased by 0.74 ˚C during the past 100 years and by the end of 21st century, it is expected to rise by 1.84 ˚C as per the IPCC (2019) report. The greenhouse gas (GHG) concentrations show that CO_2 levels continued to increase and India's annual GHG emissions is maximum from agriculture and livestock. Nevertheless, through agriculture emissions of GHGs has increased by 25 per cent from 1990 to 2016, driven by emissions from synthetic fertilizers (47%) and enteric fermentation from livestock (30%). The main source of CO_2 emissions in agriculture is by way of soil management, for example, tillage practices due to soil organic matter decomposition. Crop residue burning and use of fuel for agricultural operations are the other sources of CO_2 emissions. Climate change effects directly and indirectly on land degradation, food production, crop productivity, water supply and environmental hazards. Also it affects agricultural systems in several ways, viz., rainfall, temperature, and climate extremes (e.g., cold and heat waves) impact on plant growth and development; increase pests and diseases; bring about alarming change in biosphere environment and change in food quality.

Impact of climate change on Indian agriculture

India’s agriculture is more dependent on monsoon from the ancient periods. Any change in monsoon trend drastically affects agriculture. In the Indo-Gangetic Plain, these pre- monsoon changes will primarily affect the wheat crop (>0.5 ^{o}C increase in time slice 2010-2039). Increase in CO_2 to 550 ppm increases yields of rice, wheat, legumes and oilseeds by 10-20%. A 1 ^{o}C increase in temperature may reduce yields of wheat, soybean, mustard, groundnut, and potato by 3-7%. The major impacts of climate change will be on rainfed or un-irrigated crops, which is cultivated in nearly 60% of cropland. A temperature rise by 0.5 ^{o}C in winter temperature is projected to reduce rainfed wheat yield by 0.45 tonnes per hectare in India. Increased droughts and floods are likely to increase production variability. Recent studies done at the Indian Agricultural Research Institute indicate the possibility of loss of 4-5 million tons in wheat production in future with every rise of 1 ^{o}C temperature throughout the growing period. Rice production is slated to decrease by almost a tonne/hectare if the temperature goes up by 2 ^{o}C. Agriculture will be worst affected in the coastal regions of Gujarat and Maharashtra, as fertile areas are vulnerable to inundation and salinization.

Presently, Agricultural production systems are facing increasing competition from other sectors for limited natural resources. The availability of these resources and their quality are also being affected by unsustainable management practices and changing climatic and weather conditions. To respond to this situation, the agriculture sectors must improve their sustainability performance and adapt to the impacts of climate change in ways that do not compromise global efforts to ensure food security for all. These challenges are intimately and inextricably related, and need to be addressed simultaneously.

Climate smart agriculture

Climate-smart agriculture (CSA) is an approach for transforming and reorienting agricultural production systems and food value chains so that they support sustainable development and can ensure food security under climate change. CSA is comparatively a new approach which helps to increase agricultural production and income of the poor households through ensuring better practices in agriculture as well as reducing green-house gases emission.

In the changing climatic condition, CSA is an effective approach to enhance agricultural production and feed the people across the world. It has emerged as a framework to capture the concept that agricultural systems can be developed and implemented simultaneously to improve food security and rural livelihoods, facilitate climate change adaptation and provide additional benefits. However, the concept of CSA is still evolving and there is limited research that explores the linkages of CSA and sustainable agriculture and how the practices of CSA can be promoted to achieve food security and development goals. Therefore, it is crucial to reinforce and disseminate CSA approaches at field level for attaining a sustainable and better future.

Pillars of climate smart agriculture

The concept of CSA is built on three pillars which are described below:

1. Productivity

CSA attempts to develop practices of agriculture for increasing productivity and earning from crops, livestock, and fisheries without any adverse effect on the environment. It also helps to improve food and nutritional security. Sustainable intensification is a major element of CSA for maximum uses of natural resources. Promoting of adaptive capacity can help to enhance sustainable intensification which ultimately increases productivity.

2. Adaptation

CSA aims to minimise farmers to short-term risks, while also developing their resilience by enhancing their capacity to adapt in the perspective of longer-term stresses. Special focus is given to preserving the ecosystem which offers to farmers and others. Climate smart practices are necessary to increasing capability for climate change adaptation and increasing productivity.

3. Mitigation

CSA also aims to minimize or control GHG emissions from food, fibre, and fuel. It manages soils and trees in ways that can help to play a role as carbon layer and absorb CO_2 from the environment. According to FAO, mitigation is the capability of systems, society, group or individuals to protect, prevent, minimize, alleviate or cope with risk and recover from stresses. Adaptive capacity is necessary for a system to be resilient which faces vulnerability to stress over time.

How is climate-smart agriculture implemented

Climate-smart agriculture relates to actions in fields, pastures, forests, and oceans and freshwater ecosystems. It involves the assessment and application of technologies and practices, the creation of a supportive policy and institutional framework and the formulation of investment strategies.

Climate-smart agricultural systems include different elements such as:

- The management of land, crops, livestock, aquaculture and capture fisheries to balance near-term food security and livelihoods needs with priorities for adaptation and mitigation.
- Ecosystem and landscape management to conserve ecosystem services that are important for food security, agricultural development, adaptation and mitigation.
- Services for farmers and land managers that can enable them to better manage the risks and impacts of climate change and undertake mitigation actions.
- Changes in the wider food system including demand-side measures and value chain interventions that enhance the benefits of climate-smart agriculture.

Designing a national climate-smart agriculture approach requires the coordination of activities of a wide range of stakeholders.

Some of the areas in which we help implement climate-smart methods:

1. Crop management

Once an assessment of climate impacts and risks has been conducted, climate-smart strategies tailored to a particular landscape, farming community, or even individual farm can be determined. In cocoa, for example, pruning is essential, but it has to accord with the local climate risks: Where there is extreme rainfall, pruning should be done more often to ensure stronger trees that recover faster, whereas in prolonged dry periods, a farmer needs to avoid pruning so much that primary branches and trunks are exposed to too much sunlight. Harvesting and fermentation (in the case of cocoa) also require different practices for different climate situations. In the event of heavy rains or excessive moisture, simple solar dryers can be created from wood frames and plastic sheets to dry beans.

2. Soil management

Contour planting, a soil management practice helps reduce soil erosion. Heavy rainfall can wash away fertile top soil, especially on sloping land. Planting ground cover helps keep soil in place in the event of heavy rains-and it's extremely beneficial in drought-prone regions, too, because it helps retain moisture in the soil. In flood-prone areas, farmers can build drainage systems to keep nutrient-rich topsoil from being washed away; trenches can also help control excess water and keep soil where it needs to be. Planting on contours, such as hills or natural terraces, is an effective way to cut down on soil erosion, as well. Mulching techniques which involves the application of organic matter from crop residues to the soil can also improve soil conditions.

All practices that improve soil quality and structure also improve productivity-a core goal of all climate-smart agriculture. Healthy soils are also important carbon sinks that hold carbon dioxide and keep it out of the atmosphere, thus helping fight climate change.

3. Pest and Disease management

Global warming can give rise to pests and diseases that can reduce yields drastically and even destroy entire farms. Rising temperatures have helped the *roya* fungus, for example, to proliferate and wipe out coffee farms all over Central America. In a changing climate, the tried-and-true ways of battling pests and diseases often fail; desperate farmers may be tempted to increase the amount of pesticides, but over-application will only increase costs, harm beneficial insects and increase the risk of contaminating people and the environment.

Climate-smart agriculture trainings provide farmers with the knowledge they need to apply just the right amount and at the right time of year—to combat these newly proliferating pests. Investing in pest-resistant seedlings can also help. When it comes to weeds, we advise farmers in any climate situation to use manual weeding as much as possible, taking aim at noxious weeds while leaving soft weeds that can actually replenish soil and prevent nutrient-rich top soil from eroding.

4. Water conservation

Agriculture consumes 70 percent of the world's available supply of freshwater. As the planet continues to heat up, water shortages which is already a problem in many regions will become a more severe threat. Harvesting rainwater is one way for farms to prepare for water shortages. Communities can dig ponds lined with bamboo to better retain the water. On individual farms, there are several ways to collect rainfall, from simply placing barrels outside to creating that channel rain from roofs into barrels through a series of gutters and pipes. Traditional irrigation methods can also help address water stress on farms. Using watering cans is labor-intensive and potentially wasteful, since very dry earth can't absorb large amounts of water at once but placing bamboo sticks or bottles filled with water next to plants can create low-tech, slow-drip irrigation.

Climate change can also bring about too much water. The combination of long dry periods, which make the ground hard, followed by heavy rains, set the stage for flooding. Building drainage systems and trenches can channel excess water and protect crops from moisture-fueled diseases

Adaptation/Mitigation strategies for climate smart agriculture

1. Minimum/No disturbance of soil

Usually, tilling of the soil is done to prepare a good seedbed for easy sowing of crops and to manage weeds in the crop field. However, excessive tillage leads to the destruction of soil structure and stimulates the germination of weed seeds by bringing them to the soil surface. Following crop establishment practices are usually followed under CA.

a. Zero tillage/No tillage

In which the primary tillage is totally avoided and the secondary tillage is restricted to the crop row zone only. This technology mostly used in Rice-Wheat cropping system using Zero till-ferti-seed drill machine, which is capable of placing the seeds and fertilizers in narrow slits created by a furrow opener. This technology reduces the number of tractor operations required for field preparation and crop sowing and thus, saves fuel, energy, cost and time. Thus, it causes an increase in soil organic carbon status and leads better soil fertility.

b. Permanent bed planting

Permanent beds are prepared by tilling the soil for the first time, which can be used in subsequent years with only a little reshaping of the beds. In this technology, 2 to 3 or 4 to 5 rows of a crop can be grown on a raised bed of 60 cm (narrow bed) or 120 cm (broad bed), respectively. A furrow of 30 cm depth separates two adjacent beds. The bed planting results in saving of water (~30%), seeds, nutrients, weed suppression and better solar radiation interception.

c. Direct-Seeding of Rice (DSR)

DSR in dry unpuddled soil can be done without any primary tillage. It is a labour, fuel, time, water, and energy saving technology that emits less greenhouse gas as compared to transplanted rice. It is reported a saving of 3-4 irrigations in DSR as compared to the transplanted rice (TPR) without any yield penalty. There was also a saving in human labour use (45%) and tractor use (58%) in the DSR as compared to TPR. In various districts of Punjab, the GHG emissions under TPR was reported to be between 2.0 and 4.6 CO_2 eq/ha, whereas under DSR it ranged from 1.3 to 2.9 CO_2 eq/ha.

2. Seeding in to surface residues

Various machines are available for sowing seeds in standing surface residue and also in loose residues which normally exists when the combine is used for harvesting paddy. However, the amount of crop residue that can effectively be managed by surface retention is a matter of concern. The traditional zero-till-seed drill can operate under surface residue of up to only 3 t/ha. 'Happy Seeder' can plant wheat seed under a surface residue of up to 10 t/ha. A super straw management system (SMS) can be attached to self-propelled combine harvesters during harvesting of rice which cuts paddy straw into small pieces and spread it on the soil surface, which makes sowing of wheat easier using a happy seeder.

3. Diversification of crop species grown in sequence or associations

The rice-wheat cropping system of IGP remains fallow for 60-70 days between the harvest of wheat (April) and sowing of subsequent rice crop (July). The short-duration mungbean varieties like SML 832 and SML 668 can be grown during this fallow period. The inclusion of legumes in the cropping system acts as a break crop for various pests. The crop rotation with legumes meets the N requirement through biological fixation of atmospheric N. It is observed the C and N stocks were significantly higher under zero tillage compared to conventional tillage in soybean-wheat-hairy vetch system. Moreover, the N can be added to the soil through the inclusion of short duration leguminous crops in the cropping system that helps in organic matter build-up.

4. Precision nutrient management

Next to seeds, fertilizers are important input for food production. The overuse of inorganic fertilizers has caused major environmental problems with an estimated 60 percent nitrogen pollution caused by crops alone. By enhancing the FUE by 5 to 10 per cent, it could increase returns, reduce emissions of N_2O and significantly reduce production costs, thus giving greater profits. Chlorophyll meter (SPAD), leaf colour chart, and NDVI green Seeker are currently being used in farmer's fields. Similarly, Nutrient Expert and Crop Manager, computer/android phone-based decision support systems are progressively being used to enable the application of improved nutrient management practices in farmers's field.

5. Precision/Climate smart water management

With rising temperature and changes in precipitation patterns due to climate change, it is likely to have serious implications on water availability and thereby, affecting agriculture. There are certain technologies like DSR, SRI, aerobic rice cultivation, alternate wetting and drying, deficit irrigation, partial root drying, intermittent irrigation and micro-irrigation management are well proved for enhancing water use efficiency as well as to cope with challenges of climate change and variability. Alternate wetting and drying (AWD) is a water management technique in rice, which was developed in the 1970s to address the problem of increasing water scarcity in agriculture. Richards and Sander (2014) disclosed that 20-70 per cent reduction in methane emissions along with 25-40 per cent saving of water as compared to conventional flooded rice cultivation. Therefore, AWD serves the twin purpose of mitigating GHG emissions by reducing methane and adapting to water stress. Similarly, SRI, and DSR save 20 to 50 per cent irrigation water in rice cultivation. Micro irrigation is another vital option for high irrigation efficiency (> 90%). However, majority of the area (55.4%) covered under micro irrigation is in horticultural crops and only 7 per cent area is under field crops. Yield improvement due to drip irrigation has been reported by 35-50 per cent in sugarcane, 5-10 per cent in cotton, 15-42 per cent in castor, 20-66 per cent in groundnut and 20-26.4 per cent in potato. Since energy requirement for pumping of water using drip irrigation is 50 per cent lower than that of flood irrigation, it can be met through solar powered pumps and hence, reduces the water footprints significantly.

6. Precision land levelling

Laser land levelling includes smoothening the land surface by using laser equipped drag buckets and it creates a slope of 0 to 0.2 percent. It involves the use of large horsepower tractors equipped with laser-guided instrumentation or global positioning system (GPS) for creating the desired slope and it allows uniform water distribution with negligible losses by providing a very graded and smooth field condition. It facilitates uniformity in seed and fertilizer placement which helps to maintain optimum plant stand, enhanced nutrient acquisition and higher yield. Laser land levelling resulted in reducing irrigation water application by 25 per cent and labour requirements by 35 per cent, and an increase of net area by 3-4 per cent and wheat yield by 30 per cent as compared to conventional practices of field preparation. Thus, by increasing water use efficiency it puts less pressure on the existing water resources and helps to adapt to variable moisture environments.

7. *In situ* moisture conservation and water harvesting

Water harvesting, water conservation and improvement in irrigation accessibility and efficiency are need of the hour for boosting productivity and livelihood improvement, under changing precipitation patterns and elevated temperatures. Water harvesting methods involving decreasing runoff (contours, vegetative hedges), increasing water infiltration and reducing soil evaporation (crop residues mulch) should be advocated for better soil-water management. Water harvesting is a process of collecting runoff water into a catchment for further use. The collected water can be directly applied to the crop or stored in the soil profile for immediate crop use (runoff farming), or stored in an on-farm water tank for future uses. Areas where water is scarce due to low rainfall, simple techniques for in situ conservation, groundwater recharge, farm pond or tank and protective irrigation are important to minimize the impact of dry spells and for providing opportunities for critical irrigation). In situ water harvesting techniques include summer ploughing, random tie ridging, broad bed and furrows, ridges and furrows, and compartmental bunding, whereas ex situ techniques include creation of farm ponds. The primary objective of in situ conservation is to control soil erosion and ensure minimal runoff. In the case of drought or erratic rainfall, ex situ water management i.e., collection and storage of rain water in ponds will provide convenient water supply during dry periods through supplementary irrigation. Collection and storage of rainwater can provide a convenient and reliable water supply during seasonal dry periods and droughts. Rainwater collection can also contribute greatly to the stabilization of declining groundwater tables, decrease travel time to remote water sources and increase agricultural productivity.

8. Intercropping

Intercropping is an adaptation strategy on spatial and temporal perspective and functional diversification of different crops and it provides better utilisation of locally bound agroecosystem resources. It is an ancient practice which represents within field ecological intensification and diversification strategy maximizing the land productivity. This increase in productivity contributes to accumulation of soil organic matter in higher side and induces carbon sequestration to mitigate greenhouse gas production from agriculture. Sowing of crops along with legumes provides stable yields by efficient utilization of resources, reduces variability in crop yields and improves soil quality through atmospheric fixation of nitrogen. High leaf cover provides cooler microclimate through transpiration which in turn, reduces soil evaporation and associated soil temperatures. Deep root system of legumes can tap moisture and nutrients from deeper soil layers and does not compete with other associated shallow root crops in intercropping system

9. Mulching

Mulching involves covering the soil surface with organic or inorganic materials, which helps to moderate soil temperature and moisture, and reduce nutrient losses, salinity, erosion, etc. In the wake of climate change, elevated temperature, soil erosion, landslides, etc., mulching has regained its importance. Application of crop residue mulch at the soil air interface protects the soil against raindrop impacts, decreases runoff velocity, increasing infiltration rate and also acts as a sediment trap. Besides, mulch has favourable impact on soil quality and resilience; it moderates soil temperature and moisture regimes and has beneficial effect on crop growth and yield. Furthermore, it is quite probable that mulch enhances soil organic matter content, aggregate stability and microbial activities.

10. Weed management

Climate change has a serious impact on the interaction between crop and weed and thus, it is necessary to understand the weed interaction and dominance pattern for successful weed management. Under increased temperature scenario, C4 weeds would pose serious yield penalties. In the case of C3 crops like rice and wheat, weed problem will aggravate due to increase in CO_2. Some weed species like *D. aegyptium* and *E. colona* responded to elevated CO_2 whereas *C. rotundus* and *E. indica*, hardly responded to carbon enrichment. Besides weed shift, problems like herbicide toxicity and resistant weeds may increase as a result of continuous herbicide use and climate change. Integrated weed management (IWM) is the more applauded aspect of long-term weed management programme under climate changing scenario as it brings all feasible weed control methods into a single and co-ordinated system. Effective utilization of allelopathic crop residue mulches (wheat, barley, maize, sorghum, rye) may help to mitigate adverse climatic effects by acting as self-supporting weed management method for the concurrent as well as succeeding crops. Biological weed control methods (use of bioagents, bioherbicide) usually target the specific natural enemy weeds and thus, can be a promising method to naturally limit the weed population. Soil solarization plays a vital role in weed, nematodes and pathogen management under increased temperature conditions.

11. Nutrient management

Optimal utilization of on-farm resources as inputs such as crop residues; location and time-specific application of major nutrient fertilizers according to the needs of plant; selection of most appropriate combination of fertilizer sources for enhancing use efficiency and economic benefits; integration of nutrients from different sources along with other integrated crop management practices for sustainable crop production; and correction of deficient nutrients and rationalizing nitrogen fertilisers are some of the strategies, which can minimize the resource use and enhance efficiency, and also minimize emissions.

12. Agro advisory service

ICT has created new opportunity to ensure that farmer can get information they need. Mass media also play an important role in information distribution & in political market & public policy making Mass media are effective in awareness & even to the extent of leading an individual to involvement at intellectual level. Awareness creates curiosity about new idea in the farmers mind leading them to seek more info about it. There are different platform through which farmer access information in India. This include radio, TV, print, face-to-face etc. However, today with the rapid changes in climate pattern the agriculture practices performs by the farmers poor growth in technology. But at interiors areas the mass media will not performs proper the mobile phones are widely used in day to day activities of life worldwide. ICT are creating new opportunity to bridge the gap between information have and have not. The cost factor in face to face information dissemination at right time and difficulties in reaching the target has also created the urgency to popularize the ICT. It is the advantage of ICT that information can also be upgraded at minimum cost.

Conclusion

The fact of changing climate and its increasing variability is well established. Under the present situation, the main target is to produce sufficient amount of quality food to meet the demand of growing population while protecting the soil and environment through innovative resource conservation technologies. A precise assessment and comprehensive understanding of resource conservation technologies (RCTs) for climate change adaptation and mitigation options is essential. The adoption of CA-based RCTs with zero or minimum tillage, surface organic residue retention, and legume-based crop rotations have huge potential to augment the use efficiency of natural resources like soil, water, nutrient, carbon, energy, and labour. Besides, diverse methods of cultivation such as mechanical transplanting, the system of rice intensification, direct seeding, in addition to other improved cultivation practices like direct seeding of maize; FIRB system for the establishment of wheat and maize; precise land levelling; precision water management approaches including drip and sprinkler systems; and precision agriculture sensor-based reliable nutrient management can rationalize fertiliser application and minimize excessive use of resources. These approaches can advance the sustainability of agro-ecosystem by preserving the natural resource base with higher input use efficiency and also mitigating GHGs emissions

References

1. Aggarwal PK. Global climate change and Indian agriculture: Impacts, adaptation and mitigation Indian Journal of Agricultural Sciences. 2008; 78(10):911-919.
2. Aggarwal PK, Bhatta GD, Joshi PK, Prathapar SA, Jat ML, Kadian M. ‘Climate smart villages in South Asia’, Climate Smart Agriculture Learning Platform, South Asia, 2013.
3. Aryal JP, Sapkota TB, Stirling CM, Jat ML, Jat HS, Rai M *et al*. Conservation agriculture-based wheat production better copes with extreme climate events than conventional tillage-based systems: a case of untimely excess rainfall in Haryana, India, Agriculture, Ecosystems and Environment. 2016; 233:325-335.
4. Dhanya P, Ramachandran A. Farmers’ perceptions of climate change and the proposed agriculture adaptation strategies in a semi-arid region of south India. Journal of Integrative Environmental Sciences. 2016; 13(1):1-18.

5. Dinesh D, Frid-Nielsen S, Norman J, Mutamba M, Loboguerrero Rodriguez A, Campbell B. Is Climate-Smart Agriculture Effective? A Review of Selected Cases. CCAFS Working Paper No. 129, Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), 2015.

6. FAO. Impacts of climate change, pests and diseases on food security and poverty reduction, Special event background document for the 31st session of the committee on the world food security FAO publication, Rome, 2013, 1-10.

7. Geethalakshmi V, Palanismy K, Aggarwal PK, Lakshmanan A. Impact of climate change on rice, maize and sorghum productivity in Tamil Nadu. In Aggarwal PK (Ed.). Global climate change and Indian agriculture: Case studies from the ICAR network project New Delhi: ICAR, 2009, 13-18.

8. IPCC. International Panel on Climate Change (IPCC). Special report on Land use, Land use Change and Forestry. Summary for Policy Makers. Geneva, Switzerland, 2019.

9. Lipper L, Thornton P, Campbell BM, Baedeker T, Braimoh A, Bwalya M *et al*. 'Climate-smart agriculture for food security', Nature Climate Change, 2014, 4. https://doi:org/10.1038/nclimate2437

10. MoEFCC. Second Biennial Update Report to the United Nations Framework Convention on Climate Change. Ministry of Environment, Forest and Climate Change, Government of India, 2018.

11. NAAS. Management of crop residues in the context of conservation agriculture. Policy paper No. 58, National Academy of Agricultural Sciences, New Delhi, 2012, 12.

12. Raza A, Razzaq A, Mehmood SS, Zou X, Zhang X, Lv Y *et al*. Impact of climate change on crops adaptation and strategies to tackle its outcome: A review. Plants. 2019; 8(2):34.

Chapter - 4
Organic Farming in India: A Vision Towards a Healthy Nation

Authors

SMS Ramya
M.Sc. Scholar, Department of Agronomy, PJTSAU, Jagtial, Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana, India

N. Mahesh
Assistant Professor, Department of Agronomy, PJTSAU, Jagtial, Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana, India

Chapter - 4

Organic Farming in India: A Vision Towards a Healthy Nation

SMS Ramya and N. Mahesh

Abstract

Food quality and safety are the two important factors that have gained ever-increasing attention in general consumers. Conventionally grown foods have immense adverse health effects due to the presence of higher pesticide residue, more nitrate, heavy metals, hormones, antibiotic residue and also genetically modified organisms. Moreover, conventionally grown foods are less nutritious and contain lesser amounts of protective antioxidants. Due to potential health benefits and food safety concerns, demand for organically farmed foods has expanded in recent decades in the hunt for safer food. Organic food production is defined as cultivation without the application of chemical fertilizers and synthetic pesticides or genetically modified organisms, growth hormones and antibiotics. The popularity of organically grown foods is increasing day by day owing to their nutritional and health benefits. Organic farming also protects the environment and has a greater socio-economic impact on a nation. India is a country that is bestowed with indigenous skills and potentiality for growth in organic agriculture. Although India was far behind in the adoption of organic farming due to several reasons, presently it has achieved rapid growth in organic agriculture and now becomes one of the largest organic producers in the world. Therefore, organic farming has a great impact on the health of a nation like India by ensuring sustainable development.

Keywords: Organic agriculture, health, food safety, food quality

Introduction

Organic agriculture is one of the most frequently used ways to prevent the adverse effects of chemical agriculture. There are many organic agriculture descriptions and regarded as the most reliable and strict by the Department of Agriculture (USDA). It is characterized by using methods and substances that preserve organic agricultural products' quality until they reach the consumer. The system is intended and maintained to produce agricultural products. It was done by using compounds to satisfy any specific evolution within a scheme to preserve the long-term biological operation of the soil, ensuring effective peak management, recycling waste to remit nutrients to the soil, caring for farm animals and manufacturing agricultural products without the use of special synthetic additives or processing in compliance with the act. In its modern past, the roots of organic farms date back to the 1940's. The cause of organic agriculture had endorsed by Rodale in the United States, Lady Balfour in England, and Sir Albert Howard in India. In India, agriculture has become more and more unsustainable for the last three decades. The system has skewed towards high productivity without much regard for the environment or the individual's own life.

Meaning of organic farming

The agricultural process that uses bio fertilizers and pest control from animal or herbal waste can describe as organic farming. Organic farming was introduced to resolve the environmental harm caused by chemical and synthetic fertilizers. It means that organic agriculture is a new agriculture system that restores, maintains, and improves the ecological balance.

Aim of organic farming

- To provide quality and nutritious material to the population.
- Efficient natural resource use.
- Reduce/stop all kinds of agricultural emissions.
- Minimize prices for input.
- To sustain long-term soil fertility.

Organic farming process

Organic farming and food processing practices are wide-ranging and necessitate the development of socially, ecologically and economically sustainable food production system. The International Federation of Organic Agriculture Movements (IFOAM) has suggested the basic four principles of organic farming, i.e. the principle of health, ecology, fairness and care (Figure 1). The main principles and practices of organic food production are to inspire and enhance biological cycles in the farming system, keep and enhance deep-rooted soil fertility, reduce all types of pollution, evade the application of pesticides and synthetic fertilizers, conserve genetic diversity in food, consider the vast socio-ecological impact of food production, and produce high-quality food in sufficient quantity (IFOAM, 1998). According to the National Organic Programme implemented by USDA Organic Food Production Act (OFPA, 1990), agriculture needs specific prerequisites for both crop cultivation and animal husbandry. To be acceptable as organic, crops should be cultivated in lands without any synthetic pesticides, chemical fertilizers, and herbicides for 3 years before harvesting with enough buffer zone to lower contamination from the adjacent farms. Genetically engineered products, sewage sludge and ionizing radiation are strictly prohibited. Fertility and nutrient content of soil are managed primarily by farming practices, with crop rotation, and using cover crops that are boosted with animal and plant waste manures. Pests, diseases, and weeds are mainly controlled with the adaptation of physical and biological control systems without using herbicides and synthetic pesticides. Organic livestock should be reared devoid of scheduled application of growth hormones or antibiotics and they should be provided with enough access to the outdoor. Preventive health practices such as routine vaccination, vitamins and minerals supplementation are also needed (OFPA, 1990).

Need for organic farming

Organic cultivation has such essential advantages as maintaining the organic composition of the soil.

Natural farmers use the following:

- Preserve and boost soil fertility, biodiversity and erosion.
- Minimize exposure to hazardous products to humans, animals and the environment.
- Transparent agricultural practices in order to meet local requirements of development and local markets.

Principles of organic farming

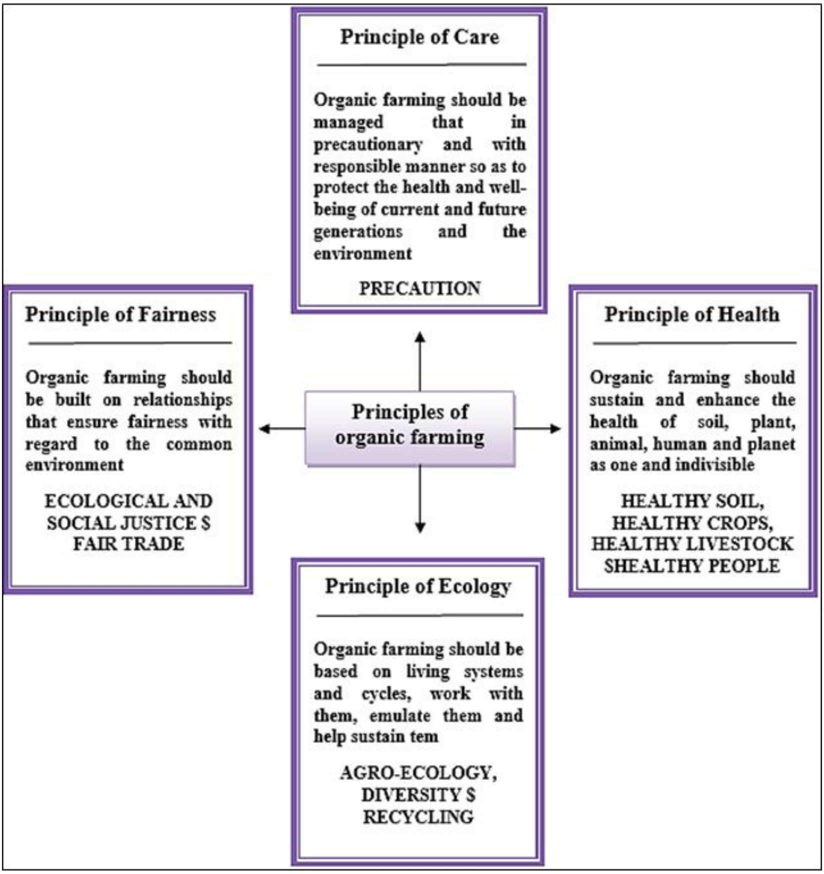


Fig 1: Principles of organic farming (Adopted from IFOAM, 1998)

Organic farming prospects

- It contributes to global health by lowering emissions.
- The risk to human and animal health is reduced as the residual level in the drug is reduced.
- It contributes to the long-term viability of agricultural output.
- It reduces agriculture output expenses while also improving soil health.
- It guarantees that natural resources are utilized at their full potential in the short term while also conserving them for future generations.

- It conserves the resources of animals and machineries while lowering the risk of crop failure.
- It improves the soil physical properties *viz.*, granulating, right tilting, good aeration, fast root penetration, boosts water retention, and reduces erosion.
- It improves the chemical qualities of the soil, such as delivering and retaining soil nutrients, reducing nutrient losses to water and the atmosphere and promoting favourable chemical interactions.

Organic farming problems

In organic farming, there are a few issues, like

- Organic manure is difficult to come by, and if it is, it might be more expensive than artificial fertilizers in terms of plant nutrients.
- Organic farm production declines in the first few years, hence organic farming should reward premium farmer pricing.
- Organic farming, production, transportation and certification criteria are beyond the comprehension of most Indian farmers.
- There is still no properly organised organic product promotion. Because of their convictions or finances, many farms in India have never been chemically controlled, cultivated, or converted back to organic farming. Thousands more farmers cultivate millions of hectares of land but are not certified as organic. Their items sell for the same price as traditional products in the general market, or sell solely goodwill and trust, such as organics, through chosen outlets and regular specialty markets. These farmers would never be able to afford certification due to the high fees and extensive documentation required by certifiers.

Organic farming supporting schemes in Indian government

Cultivable land area under organic farming has increased from 11.83 lakh hectare in 2014 to 29.17 lakh hectare in 2020 in the country due to the focused efforts of the government. Taking cue from the success of the organic initiatives, a target of 20 lakh hectare additional area coverage by 2024 is envisaged in the vision document. The government of India provides assistance for promoting organic farming through different schemes.

1. Paramparagat Krishi Vikas Yojana (PKVY)

Paramparagat Krishi Vikas Yojana supports organic farming group together with the certification of PGS (Participatory Guarantee System). The scheme facilitates cluster recruitment, training, certification and marketing of assistance had given (Rs. 50,000 ha^{-1} for 3 years), 62% (Rs.31, 000) which would provide farmers with an opportunity to make bio-inputs.

2. Mission Organic Value Chain Development for North Eastern Region (MOVCDNER)

The scheme promotes third party certified organic farming of niche crops of north east region through Farmer Producer Organizations (FPO) with focus on exports. Farmers are given assistance of Rs 25,000 per hectare for three years for organic inputs including organic manure and bio fertilizers among other inputs.

3. Capital Investment Subsidy Scheme (CISS) under Soil Health Management Scheme

Under this scheme, 100 percent assistance is provided to state government, government agencies for setting up of mechanized fruit and vegetable market waste, agro waste compost production unit up to a maximum limit of Rs 190 lakh per unit (3000 Total Per Annum TPA capacity). Similarly, for individuals and private agencies assistance up to 33 percent of cost limit to Rs 63 lakh per unit as capital investment is provided.

4. National Mission on Oilseeds and Oil Palm (NMOOP)

Under the mission, financial assistance at 50 percent subsidy to the tune of Rs 300 per hectare is being provided for different components including bio-fertilizers, supply of Rhizobium culture, Phosphate Solubilizing Bacteria (PSB), Zinc Solubilizing Bacteria (ZSB), Azatobacter, Mycorrhiza and vermin compost.

5. National Food Security Mission (NFSM)

Financial assistance had given under the NFSM, which is 50 percent of the cost limit restricted to Rs 300 per Hectare to promote biomass fertilizers. In accordance with the conditions of certified land of 1.94 million hectares, India ranks at a ninth place according to international data on resource data from the Research Institute of Organic Agriculture and the International Federation for Organic Agricultural Movement (IFOAM) Statistics 2020. Intending to facilitate the use of biological on-farm inputs for chemical-free farming in Bharatiya, Prakritik Krishi Padhati (BPKP) of the PKVY had initiated. In order to stimulate natural agriculture under the BPKP, Andhra Pradesh and Kerala occupied one lakh hectare and 0.8 lakh hectare, each. Similarly, in 2020-21 continuous field certification and certification support for individual farmers were introduced to put conventional and organic farmers into default. Government agencies, Primary Agricultural Credit Societies (PACS), FPOs, and others could take loans for building an additional value infrastructure for organic produce under Agriculture Infrastructure Fund (AIF) of Aatmanirbhar Bharat's (1 lakh crore).

Organic farming techniques in India

- It promotes organic farming through agro-tourism, which attracts urban families to organic farming and pays farmers well.
- Retailing, packaging, and labeling can all help with organic goods marketing, including appealing packaging made from organic waste.
- High-value crops with trade sustainability, industrial usage, and export potential should be considered.

With its huge geographical size and diverse eco zones, India has enormous potential to profit from organic farming. Small farmers in India, on the other hand, are limited by land availability, registration, a lack of local markets, and other considerations. As a result, the government and non-governmental groups must work together to remove barriers that prevent small farmers from using organic farming to meet their nutritional needs while preserving soil, water, energy and biological resources.

Future prospects of organic farming in India

India is an agriculture-based country, with farming and allied sectors employing 67 percent of the population and 55 percent of the workforce. Agriculture provides for the fundamental needs of India's fastest-growing population, accounting for 30% of total GDP. Organic farming has been discovered to be an indigenous Indian tradition that has been performed for millennia in various rural and farming areas. The introduction of contemporary technology, combined with a growth in population, resulted in a preference for conventional farming, which entails the use of synthetic fertilisers, chemical pesticides, and genetic modification techniques, among other things.

Even in developing nations like India, demand for organically grown product is increasing as people become more aware of food safety and quality and the organic process has a significant impact on soil health because it is free of chemical pesticides. Organic farming also has a lot of potential for making money. (Bhardwaj and Dhiman, 2019). India's soil is rich in a variety of naturally occurring organic nutrient supplies that enable organic farming. (Adolph and Butterworth, 2002; Reddy, 2010; Deshmukh and Babar, 2015).

The technology aims to reactivate soil-plant-microflora dynamics by restoring the population and efficiency of native soil microflora, and reactivate the two plant kingdom defense mechanisms of nutrient use efficiency and superior plant immunity against pest and disease infection by restoring the population and efficiency of native soil microflora. (Barik and Sarkar, 2017).

Conclusions

Organic farming produces food that is more nutritious and safe. Organic food is becoming increasingly popular as consumers seek for meals that are perceived to be healthier and safer. As a result, organic food may ensure food safety from farm to fork. Organic farming is more environmentally friendly than conventional farming. Organic farming promotes consumer health by keeping soil healthy and maintaining environmental integrity. Furthermore, the organic produce market is now the world's fastest expanding market, including in India. Organic agriculture enhances a nation's consumer health, its ecological health, and its economic growth by generating income in a holistic manner. India is currently the world's greatest organic producer and with this perspective, we can conclude that boosting organic farming in India will help to establish a nutritionally, environmentally and economically healthy nation in the not-too-distant future.

References

1. Adolph B, Butterworth J. Soil fertility management in semi-arid India: its role in agricultural systems and the livelihoods of poor people. Natural Resources Institute, UK, 2002.
2. Barik A, Sarkar N. Organic Farming in India: Present Status, Challenges and Technological Break Through. In: 3rd International Conference on Bio-resource and Stress Management, Jaipur, India, 2017.
3. Bhardwaj M, Dhiman M. Growth and performance of organic farming in India: what could be the future prospects? Journal of Current Science. 2019; 20:1-8.
4. Deshmukh MS, Babar N. Present status and prospects of organic farming in India. European Academic Research. 2015; 3:4271-4287.
5. Reddy SB. Organic farming: status, issues and prospects-a review. Agricultural Economics Research Review. 2010; 23:343-358.

Chapter - 5
Different Organic Manures Application and Its Impact on Growth and Yield of Glori Lily (*Gloriosa superba* L.)

Authors

S. Deivasigamani
Assistant Professors, Department of Agronomy, Krishna College of Agriculture and Technology (KRISAT), (Affiliated to Tamil Nadu Agricultural University, Coimbatore-3), Srirengapuram, Madurai, Tamil Nadu, India

D. Beulah Esther
Assistant Professors, Department of Agronomy, Krishna College of Agriculture and Technology (KRISAT), (Affiliated to Tamil Nadu Agricultural University, Coimbatore-3), Srirengapuram, Madurai, Tamil Nadu, India

S. Gowtham
Assistant Professors, Department of Agronomy, Krishna College of Agriculture and Technology (KRISAT), (Affiliated to Tamil Nadu Agricultural University, Coimbatore-3), Srirengapuram, Madurai, Tamil Nadu, India

Chapter - 5

Different Organic Manures Application and Its Impact on Growth and Yield of Glori Lily (*Gloriosa superba* L.)

S. Deivasigamani, D. Beulah Esther and S. Gowtham

Abstract

The field experiment were conducted at the farmer's field at Devanur village of Ariyalur District, Tamil Nadu during July 2007-December 2009 to study the effect of different Organic manures application and its impact on growth and yield of glori lily (*Gloriosa superba* L). The experiment was conducted in Randomized Block Design (RBD) with five replications. The treatments consisted of different organic manures *viz.*, T_1-Control, T_2-FYM @ 12.5 t ha^{-1}, T_3-EFYM @ 750 kg ha^{-1} and T_4-Pressmud compost @ 5t ha^{-1}. Among the organic manures, application of EFYM@ 750 kg ha^{-1} (T_3) recorded the highest growth and yield attributes like plant height (cm), LAI, DMP (kg/ha), number of branched $plant^{-1}$, days to fifty percent flowering and number of pods $plant^{-1}$, number of seeds pod^{-1}, test weight (g), seed yield and tuber yield. Based on the above results, it can be concluded the use of organic farming with EFYM is found to be an appropriate agro-technique for augmenting the productivity of glori lily.

Keywords: *Gloriosa superba*, organic manures, growth and yield performance

1. Introduction

Glory lily has one of the medicinal plants which have contributed to the development of ancient Indian materia medica. In one of the earliest treatises on Indian medicine, the charak, samhita (1000 B.C.) records the use of over 840 drugs of plant origin. Even though there has been a tremendous development in the field of synthetic drugs and antibiotics during the recent years, plants still remain one of the major sources of drugs in traditional as well as in modern medicine throughout the world. Among them, the Glory lily (*Gloriosa superba* L.) has attracted large-scale cultivation in recent times. *Gloriosa superba* L. belongs to the family Liliaceae, being locally called as "Kanvali kizhangu" or Karthigai kizhangu" or Kalappai kizhangu (or)

“Kanthasth” in Tamil. It resumes new growth by July-September and produces flowers during October-November (Swarnapriya *et al.,* 1995) [56].

It is a native to tropical Asia and Africa and found growing throughout tropical India upto an altitude of 2500m (Chopra *et al*., 1956) [11]. Commercial cultivation of this crop is mostly confined to the Southern states of India (Ramesh Bedi, 1964) [39]. Glory lily is a large glabrous, herbaceous branching climber with narrow leaves ending in a spirally twisted climbing leaf tip tendril (Biswas, 1989) [6]. It arises from a perennial, fleshy tuberous rhizome. The flowers are large, axillary, stout and solitary. The sepals and petals are erect and greenish at emergence which become reflected and turn light yellow on maturity. With age, they become dark in colour, finally changing from scarlet to crimson.

The medicinal value of glory lily is commendable which is attributed to the presence of alkaloids, chiefly ‘colchicine’ (C_{22} H_{25} O_6 N MP-151-152 °C) and ‘Gloriosine’ (C_{22} H_{25} O_6 N MP-248-250 °C). Recently, a new alkaloid namely 1, 2 Dimethyl colchicine has been isolated from seeds (Chaudhuri and Thakur, 1993) [10]. Colchicine extracted from the tubers and seeds are used in the treatment of ‘gout’ and ‘rheumatism’. It is also used by breeders to induce polyploidy in crop plants. Sarin *et al.* (1974) [43] reported that the seeds contain 0.81 per cent total alkaloids and 0.60 per cent colchicine, whereas the tubers have 0.57 per cent total alkaloids and 0.05 per cent colchicine on dry weight basis, which indicates the greater commercial value of seeds.

The drug extracted from the seed is bitter, pungent and astringent in taste. In Ayurvedic system of medicine, the underground rhizomes are used since ancient times as an anthelmintic, anti-inflammatory and anti-leprotic. The drug from the tuber is a gastro-intestinal irritant and may cause vomiting or purging. It is useful in dermatosis, piles, chronic ulcers, colic pain and as a cataplasm in neuralgic pains. The white starchy powder made from the tubers after washing with water is used in the treatment of gonorrhoea and the leaf juice is used for killing head lice. The underground stocks have been used as an abortifacient and hence the name “Garbhadharini”. The tubers are administered to cattle for expulsion of worms and also used as an adulterate of Aconite (Rao, 1914) [40].

Gloriosa superba is the only species occuring in India. The alkaloid is accumulated mainly in the tuber and leaves of G. *superba*. There are few reports on cell and root cultures of G. *superba* for the biotechnological production of colchicine (Sivakumar *et al.,* 2004) [51]. Feeding experiments with precursors of the biosynthetic pathway have been reported to increase the colchicine content of root cultures to 0.19% (Ghosh *et al*., 2002) [15]. The roots were harvested, dried and powdered and then extracted for 6 hr. in a Soxhlet extractor with methanol. The extract was diluted with distilled water partitioned against n-hexane and finally the aqueous phase containing colchicine was extracted with chloroform. Chloroform extracts were evaporated to dryness and the residue was dissolved in 1 ml HPLC grade methanol, filtered through 0.22 μm filter and subjected to HPLC following the method reported earlier (Ghosh *et al*., 2002) [15].

According to Kirthikar and Basu (1975) [22], the root pieces after certain pre-treatments and preservation are administered as an antidote in cobra poisoning. In scorpion and centipede stings, on application of the root paste relief is obtained. At present, glory lily cultivation in India is confined to states like Tamil Nadu and Goa. In Tamil Nadu, the cultivation has recently spread in isolated pockets in the districts of Salem, Erode, Dharmapuri, Nagapattinam, Dindigul and Ariyalur. Being a newly domesticated crop, the appropriate production technologies for this medicinal plant have not yet been standardized on a scientific footing.

Among different technologies, use of organics for increasing the production is emphasized because continuous use of chemical fertilizer has led to several hazards in soil by heavy withdrawal of nutrients (Prasad and Singh, 1981) [38] and nutrient imbalance (Singh *et al.*, 1989) [50] and ultimately resulting in the reduction of crop yields. The bulky organic manure requires improvement in quality with reference to its nutrient content through enrichment, Shailendranath and Rao (1979) [47] reported pre-treatment of FYM with urea and phosphate fertilizer had significantly increased growth and yield on medicinal plants. Nayak (1993) [31] reported that application of one tone of EFYM ha^{-1} was on par with six tons of conventional FYM ha^{-1} in increasing yield on medicinal plants.

2. Effect of organic manures

2.1 Effect of farmyard manure on growth and yield

Cerna (1990) [9] found that NPK application in the absence of FYM retarded formation of vegetative organs and subsequently reproductive organs in capsicum. In Chilli, Meera Nair and Peter (1990) [28] revealed that FYM favourably increased the vegetative mass, dry weight, plant height and photosynthetic potential. Application of organic manures has various advantages like increasing soil physical properties, water holding capacity, and organic carbon content apart from supplying good quality of nutrients to cassava crop (Savithri *et al.,* 1991) [45]. Kuppuswamy *et al.* (1992) [26] observed that application of FYM @ 10 t ha^{-1} increased the grain yield from 6.61 to 7.33 t ha^{-1} and also significantly enhanced straw yield in rice. Pandita and Bhan (1992) [33] observed that combination of sand, soil and FYM in the ratio 1:1:1 registered highest yield of marketable spears (22.42 q ha^{-1}) in *Asparagus officinalis*.

Shindhu *et al.* (1992) [49] reported that application of FYM @ 20 t ha^{-1} to soil increased the P^H, EC, exchangeable potassium and available nitrogen on rice crop. Balu (1993) [4] reported that application of FYM along with Fly ash increased the available P and water-soluble P and K contents of post-harvest soil on rice crop. The effect of various quantities of animal manure on horticultural crops was studied by Postma (1995) [37] and reported that bulbous and tuberous crops produced higher yield with animal manure applied @ 12.5 t ha^{-1} when compared to control. In *Asparagus racemosus*, Srivastava and Pahapalkar (1997) [53] reported that yield was highest on the beds amended with FYM. Zdravkovic *et al.* (1997) [61] reported that in carrot FYM application produced the greatest mean yield of 48.35 t ha^{-1} compared with control (35 t ha^{-1}).

Farmyard manure is the product of agricultural and domestic wastes. It includes various farm wastes like straw, stalk and other crop residues. It also includes residues and domestic wastes like animal excreta and sewage etc. FYM is a complete manure, on an average FYM contains 0.4-1.5% N, 0.3-0.9%, P and 0.3-1.9% K on dry weight basis (Rekhi and Benbi, 1999) [41]. Briajdar *et al*. (2000) [7] reported that application of FYM @ 10 t ha^{-1} and 15 t ha^{-1} recorded 12575 kg ha^{-1} and 12925 kg ha^{-1} tuber in sweet potato respectively. Further, application of FYM @ 15 t ha^{-1} recorded 1735 kg ha^{-1} dry matter yield. Satyapal Singh *et al*. (2002) [44] envisaged that in potato, number of 'N' and 'B' grade tubers $plant^{-1}$ increased significantly with the application of FYM @ 20 t ha^{-1} combined with Gypsum @ 5.4 t ha^{-1}. In turmeric, application of manda compost @ 10 t ha^{-1} significantly increased plant height and number of fillers and leaves per plant (Nakamura *et al.,* 2001) [30].

Amzad Hossain *et al.* (2002) [3] reported that plant height, number of leaves $plant^{-1}$ and tillers were significantly increased with application of menda compost in turmeric and sweet bell pepper than with the normal compost. Application of FYM @ 15 t ha^{-1} produced the highest bulb weight (74.5 g) with the total onion yield of 291.02 q ha^{-1} (Dimri and Singh, 2005) [14].

Patil *et al.* (2005) [35] stated that balanced fertilizer use along with organic manures like FYM is considered as promising agro-techniques to sustain yield and restore soil fertility. Patil *et al.* (2005) [35] noticed that leaf dry matter production was maximum (6.46 g $plant^{-1}$) when onion crop received 30 t of FYM. Further, the dry bulb weight of onion also influenced by application of 30 t of FYM ha^{-1}. Mohamed Amanullah *et al.* (2006) [29] reported that among the organic manures viz., FYM @ 25 t ha^{-1}, poultry manure @ 10 t ha^{-1} and composted poultry manure @ 10 t ha^{-1}, application of composted poultry manure @ 10 t ha^{-1} recorded higher cassava tuber yield than other manures.

According to Amzad Hossian and Yukio Ishimine (2007) [2], application of FYM showed an excellent efficacy on growth parameters and yield of turmeric over control. They also found that the yield of turmeric increased four-five times with application of FYM in dark red soil and grey soil, whereas the manure applied in red soil resulted three times higher yield than control.

2.2 Effect of pressmud compost on the growth and yield

Pressmud (or) filter cake, a by-product obtained from sugar factory is a soft, spongy, amorphous and dark brown to brownish material which contains sugar, fibre, coagulated colloids, including albuminoids, inorganic salts and soil particles. According to Kala (1981) [21]. Pressmud is a rich source of Carbon (35-37%), N, (1-0-1.51%), P_205 (2.5-3.5%) and (0.5-0.81) K_2O. Application of Pressmud at 20 t ha^{-1} significantly increased the plant height, grain and straw yield of ragi (Indira Raja and Raja, 1981) [17]. Yaduvanshi *et al.* (1990) stated that pressmud has 1.70 per cent N, 1.60 per cent P_2O_5, 1.44 per cent K_2O, 248 mg kg^{-1} Zn, 2450 mg kg^{-1} Fe and 150 mg kg^{-1} Mn and the pH is 6.45.

Yaduvanshi and Yadav (1992) [60] stated that use of 6 t ha^{-1} of pressmud cake saved 75 kg N ha^{-1} from chemical fertilizer. Bhat *et al.* (1993) [5] reported that application of pressmud at 20 t ha^{-1} increased tobacco yield to the tune of 1.58 t ha^{-1} over FYM at 20 t and green manure at 10 t ha^{-1}. According to Abubacker and Rao (1995) [1], application of 20 and 30 t ha^{-1} of pressmud increased the shoot, root and leaf length in rice.

Jain *et al.* (1995) [20] in soybean stated that sugar pressmud @ 5 t ha^{-1} resulted in the highest nodule number (68.67), dry nodule weight (276 mg/plant) and dry shoot weight (11.92 g $plant^{-1}$). Kumar *et al.* (1996) [24] confirmed that pressmud and paddy husk combination were found to substitute 25 per cent of the recommended fertilizers in getting higher cane and sugar yields. Tompe and More (1996) [58] in sunflower revealed that total N, P and K uptake were highest with 10 t pressmud ha^{-1} and half the recommended fertilizer rate of 40:60:40 kg ha^{-1} of NPK. Subramaniyan and Wahab (1997) [55] reported that application of biodigested pressmud at 10 t ha^{-1} registered the highest grain yield in rice.

Solaimalai *et al.* (2001) [52] reported that pressmud is rich in many plant nutrients and it also has properties to ameliorate degraded soils. Krishnamurthy *et al.* (2002) [23] observed that application of pressmud @ 10 t ha^{-1} recorded 17.2, 22.6 and 22.0 per cent increase in plant height, number of tillers per plant and rhizome yield of turmeric, respectively over control.

2.3 Effect of Enriched Farm Yard Manure (EFYM)

Shailendranath and Rao (1979) [47] reported that pre-treatment of FYM with phosphate fertilizer had significantly increased grain and straw yield of finger millet. EFYM not only supplies a variety of macro and micro nutrients to the soil, but also improves the physico-chemical and biological properties of the soil which helps to maintain the soil productivity and soil health (Cooke, 1982) [12]. Sagare *et al.* (1986) [42] observed that enriched organic manure with rock phosphate or super phosphate increased the shoot and root ratio of maize. Singh (1989) [50] reported that the enrichment of organic manures with mineral nutrients not only enhanced the rate of decomposition but also improved the nutrient status of the soil.

Madhumita Das *et al.* (1991) [27] reported that the incubation of phosphatic fertilizer with farmyard manure increased the yield of maize. Studies by Sharma and Mitra (1991) [48] revealed that there was a marked improvement in the growth and yield of rice due to enriched manuring. Nayak (1993) [31] stated that application of EFYM @ 1 t ha^{-1} was on par with application of FYM @ 6 t ha^{-1} in increasing finger millet yield. The growth and yield of maize were increased significantly with application of enriched FYM. Enriched FYM increased grain yield by 40% compared to conventional FYM (Tolessa and Friesen, 2001) [57]. Senthilkumar *et al.* (2004) [46] reported that the treatment with FYM + Enriched FYM showed higher turmeric rhizome yield (21.6 per cent) than the FYM alone treatment (9.1 per cent). Among the manurial treatments, NPK + FYM + EFYM recorded the highest leaf dry matter (760 kg ha^{-1}) than NPK+FYM (713 kg ha^{-1}) and normal application (639 kg ha^{-1}) respectively. Application of NPK + FYM + EFYM recorded the highest rhizome dry matter yield (2430 kg ha^{-1} than NPK + FYM (2183 kg ha^{-1}) and no manure (1184 kg ha^{-1}).

Experiment materials and methods

Field Experiment was conducted to study the effect of organic nutrients on the growth, flowering and yield of Glory lily (*Gloriosa superba* L.) during

2009 under rainfed conditions at the farmer's field, Devanur village, Ariyalur district of Tamil Nadu. The details of materials used and methods adopted during the experimentation are furnished in this chapter.

3. Materials

3.1 Location of the experimental field

Devanur is located at an elevation of 65 m above MSL, at a latitude of 11°14′ N and longitude of 79°18′ E).

3.1.2 Weather and Climate

The mean maximum temperature is 32.2 °C and the mean minimum temperature is 21.5 °C. The mean annual rainfall is 946 mm, of which 670 mm is received during North-East monsoon (Oct.-Dec.), 220 mm during South-West monsoon (June-Sept.) and 56 mm as summer showers (March-May). The mean relative humidity is 72 per cent.

3.1.3 Soil

The soil was red loamy soil texture, low in available nitrogen, medium in available phosphorus and high in available potassium. The details of soil analysis are furnished is Table 1.

3.1.4 Crop and Variety

The "Red Kandha malar" variety of *Gloriosa superba* L. is used for the field experimentation.

3.1.5.1 Preparation of EFYM

The required quantity of conventional FYM was enriched separately with 100% each of the recommended N′ and P′ fertilizers and their combinations. The materials were thoroughly mixed and heaped. They were incubated for three months at 80 per cent moisture. The heaps were covered with polythene sheet [12] (Cooke, 1982).

Table 1: Physico-chemical properties of the soil

	Particulars	Value
A.	**Mechanical analysis (Piper, 1966)**	
1.	Coarse sand (%)	36.62
2.	Fine sand (%)	14.29
3.	Silt (%)	12.01
4.	Clay (%)	16.21
5.	Textural class	Red loam

B,	Chemical analysis	
1.	Organic matter (%) (Walkley and Black, 1934) [59]	0.70
2.	Organic carbon (%) (Walkley and Black, 1934) [59]	0.41
3.	Soil reaction (pH) (Jackson, 1973) [18]	6.5-7
4.	Electrical conductivity (dSm^{-1}) (Jackson, 1973) [18]	0.10
5.	Available 'N' kg ha^{-1} (Subbiah, 1990) [54]	231.39
6.	Available 'P_2O_5' kg ha^{-1} (Olsen *et al.* 1954) [32]	16.82
7.	Available 'K_2O' kg ha^{-1} (Stanford and English, 1949) [62]	293.68

3.2 Methods

3.2.1 Design of the experiment

The experiment was laid out in RBD design with five replications. Five plants in each treatment were marked for periodical observation.

3.2.2 Experimental details

Season	: July –Dec 2009
Plot area	: 5.0 m x 4.0 m
Date of sowing/planting	: 20.07.09
Date of harvest	: Dec-2009

3.2.3 Treatment details

T_1 - No organic manure (RDF)

T_2 - Farmyard manure @ 12.5 t ha^{-1}

T_3 - Enriched Farmyard manure @ 750 kg ha^{-1}

T_4 - Pressmud compost @ 5 t ha^{-1}

The RDF was supplied through common dose of 120:50: 75 kgs of NPK ha^{-1} was followed.

Table 2: Nutrient content of FYM, EFYM and Pressmud

Constituent	FYM	EFYM	Pressmud
Total solid (%)	45	57	73
Moisture (%)	51	43	55
Organic carbon (%)	28	25	37
C/N Ratio	20:1	18:1	30:1
Nutrient TS -basis			
Nitrogen	1.5	1.39	1.51
Phosphorus	0.61	0.24	3.5
Potassium	0.81	0.67	0.81

Copper (ppm)	11	14	110 (mg)
Manganese (ppm)	155	154	150 (mg)
Zinc (ppm)	60	70	248 (mg)
Iron (ppm)	185	220	2450 (mg)

3.3 Cultural practices

3.3.1 Field preparation

The experimental area was ploughed with a tractor and levelled. Trenches of 30 cm wide, 30 cm deep and length of 100 m were formed at a spacing of 100 cm and the plant to plant spacing was kept as 30 cm.

3.3.2 Collection and Preparation of seed tubers

Healthy Gloriosa tubers of uniform size were procured from a farmer cultivating glory lily at Elamangalam village, Ariyalur district. The tubers were transported carefully without damaging the sprouting buds and stored temporarily in thick layer of river sand in a cool dry shady place. Uniformly sized (50-60 g) healthy tubers with good growing tips were selected for planting.

3.3.3 Irrigation

The plots were irrigated once in 3 days during the initial stages of sprouting.

3.3.4 Staking

Each plant was individually staked in such a way that the growing tips trail on them.

3.3.5 Weeding and Plant protection

Need based weeding and plant protection measures were taken.

3.4 Biometric observations

Observations on different characters were recorded on five plants in each treatment and the mean was worked out.

3.4.1 Growth attributes

3.4.1.1 Plant height

The plant height was recorded at 60, 90 and 150 days after planting from the ground level to the tip of the main branch when held vertically and expressed in cm.

3.4.1.2 Number of primary branches per plant

The number of branches present on the main stem at the time of final harvest was counted and recorded.

3.4.1.3 Number of secondary branches per plant

The number of branches on each primary branches at the time of final harvest was counted and recorded.

3.4.1.4 leaf area index (LAI)

The total number of leaves present at three stages viz. 60, 90 and 150 days was counted and recorded.

$$LAI = \frac{\text{Leaf area}}{\text{ground area}}$$

This parameter was calculated by taking the maximum length and width of leaf and by using the formula LA = L x B x F as suggested by Carow (1977) [8]. The factor (F) used was 0.54 and leaf area was recorded at three stages viz., 60, 90 and 150 days.

3.4.1.5 Dry matter production

One representative plant from each plot was uprooted at harvest stage and samples were oven-dried at 80 ± 5 °C for 48 hours till a constant weight was recorded. The dry matter weight ha^{-1} was computed and expressed in DMP kg ha^{-1}.

3.4.2 Flowering, fruit set and pod characters

3.4.2.1 Days to fifty per cent flowering

The number of days taken to produce 50 per cent flowering was recorded.

3.4.2.2 Length of pod

The length of ten pods from each plot was measured from the base to the tip and their mean was expressed in cm.

3.4.2.3 Harvest

As and when the pods mature, harvesting was done. There were altogether 5 pickings in a total crop period of 160 days.

3.4.3 Yield attributes

3.4.3.1 Number of pods per plant

The total number of pods harvested per plot was counted and recorded.

3.4.3.2 Number of seeds per pod

Ten pods were randomly selected from each plot and the number of seeds in each pod was counted and the average seed number per pod was worked out.

3.4.3.3 Hundred seed weight

This was recorded by weighing 100 seeds in each treatment from the composite sample and their average was worked out and expressed in gram.

3.4.3.4 Seed yield per hectare

The total yield of seeds per plot was recorded by adding the seed yield of individual plants in each plot and recorded in gram. From the value of plot yield, the yield per hectare was estimated and expressed in kilogram.

3.4.3.5 Fresh weight of tubers

The tubers were carefully dug out after the final harvest from each plot and were weighed and the weight was expressed in kilogram per hectare.

3.4.4 Economic analysis

Based on the prevailing market rates, the gross return per hectare was worked out. The net return was calculated by deducting the expenditure from gross return. The benefit cost ratio (B: C ratio) was worked out by dividing the gross return by expenditure incurred.

Net return = Gross return-Cost of cultivation

$$\text{B:C ratio} = \frac{\text{Gross return (Rs. ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs. ha}^{-1}\text{)}}$$

3.5 Soil pH and EC

The soil solution was prepared with water at 1:2 (soil: water) ratio. The soil pH was estimated using Elico pH meter as per the procedure described by Jackson (1973) [18]. The EC was measured in the 1:2 water suspensions with Elico-conductivity meter (Jackson, 1973) [18].

3.5.1 Organic matter

The organic carbon content was determined by the method suggested by Walkley and Black (1934) [59]. It was computed to organic matter by multiplying with the factor 1.724 and expressed in percentage.

4. Experimental results

The results of the field experiments were conducted at farmer’s field, Devanur village, Ariyalur District of Tamil Nadu during 2009 to study the effect of organic manures on the growth, flowering and yield of glori lily are presented in this chapter.

4.1 Growth attributes

4.1.1 Plant height

The observations recorded on plant height at 60, 90 and at harvest are furnished in Table 3. The plant height at different growth stages showed significant variations. Among the treatments, application of EFYM @ 750 kg ha^{-1} (T_3) was found to be significantly superior over other treatments by recording the highest plant height of 145.80, 181.10 and 207.80 cm at 60, 90 and at harvest, respectively. The least plant height of 107.93, 146.93 and 165.73 cm at 60, 90 and at harvest respectively was recorded under (T_1-control).

Table 3: Effect of Organic manures on plant height (cm) and leaf area index of glori lily

Treatment details	Plant height (cm)			Leaf area index		
	60 DAP	90 DAP	150 DAP	60 DAP	90 DAP	150 DAP
T_1	107.93	146.93	165.73	0.15	0.31	0.38
T_2	128.93	162.86	182.93	0.23	0.42	0.49
T_3	145.80	181.13	207.80	0.25	0.57	0.64
T_4	132.40	160.46	185.60	0.24	0.39	0.51
$S.E_D$ CD (p = 0.05)	4.38 10.72	4.50 11.03	7.23 17.69	0.02 0.06	0.03 0.09	0.03 0.08

4.1.2 Leaf area index

The observations recorded on LAI at 60, 90 at harvest are furnished in Table 3. All the treatments significantly influenced the LAI of glori lily at different growth stages. Among the treatments, application of EFYM @ 750 kg ha^{-1} (T_3) recorded the highest LAI of 0.25, 0.57 and 0.64 at 60, 90 and at harvest, respectively. It was followed by the treatment of pressmud @ 5 t ha^{-1} (T_4) which recorded LAI of 0.24, 0.39 and 0.51 at 60, 90 and at harvest respectively. The lowest LAI of 0.15, 0.31 and 0.38 at 60, 90 and at harvest respectively was recorded under control (T_1).

4.1.3 Number of primary branches $plant^{-1}$

The observations recorded on number of primary branches $plant^{-1}$ at 60, 90 and at harvest are furnished in Table 4. Number of primary branches $plant^{-1}$ at different growth stages showed significant variations. Among the treatments, application of EFYM @ 750 kg ha^{-1} (T_3) was found to be significantly higher than other treatments. It recorded the highest number of primary branches plant^{-1} of 3.46, 4.00 and 4.13 at 60, 90 and harvest, respectively. The least number of primary branches plant^{-1} of 3.00, 3.13 and 3.13 respectively was recorded under control (T_1).

Table 4: Effect of Organic manures on primary branches and secondary branches plant^{-1} of glori lily

Treatment details	Primary branches plant^{-1}			Secondary branches plant^{-1}		
	60 DAP	90 DAP	150 DAP	60 DAP	90 DAP	150 DAP
T_1	3.00	3.13	3.13	9.53	12.46	10.26
T_2	3.26	3.53	3.26	11.20	13.73	11.13
T_3	3.46	4.00	4.13	12.33	15.60	14.93
T_4	3.27	3.60	3.33	10.20	13.40	11.60
$S.E_D$	0.08	0.25	0.49	0.38	0.95	0.63
CD (p = 0.05)	0.10	0.38	0.85	0.66	1.52	1.54

4.1.4 Number of secondary branches plant^{-1}

The observations recorded on number of secondary branches plant^{-1} at 60, 90 and at harvest are furnished in Table 4. All the treatments had significant influence on the number of secondary branches plant^{-1}. Among the treatments, application of EFYM @750 kg ha^{-1} (T_3) was found to be significantly superior over other treatments. It recorded the highest number of branches plant^{-1} of 12.33, 15.60 and 14.93 at 60, 90 and at harvest, respectively. The least number of branches plant^{-1} of 9.53, 12.46 and 10.26 at 60, 90 and harvest, respectively was recorded under control (T_1).

4.1.5 Dry matter production (DMP)

The data recorded on dry matter production (kg ha^{-1}) at harvest stage are presented in Table 5. All the treatments had significant influence on the dry matter production. Among the treatments, application of EFYM @ 750 kg ha^{-1} (T_3) was found to be significantly superior over other treatments. It recorded the highest DMP of 12771.02 kg ha^{-1} at harvest. The least DMP of 9900.21 kg ha^{-1} at harvest was recorded under control (T_1).

Table 5: Effect of Organic manures on Days to Fifty per cent flowering and DMP kg ha^{-1} of glory lily

Treatment details	Days to Fifty per cent flowering	DMP kg ha^{-1}
	Fifty per cent flowering	At harvest
T_1	67.93	9900.21
T_2	66.26	11499.93
T_3	65.53	12771.02
T_4	67.33	12127.38

S.E$_D$ CD (p = 0.05)	0.32 0.57	14.58 35.69

4.2 Flowering, fruit set and pod characters

4.2.1 Days to fifty per cent flowering

The observations on days taken to fifty per cent flowering are presented in Table 5. There was significantly influenced on days to 50 per cent flowering due to different treatments. Among the treatments, application of EFYM@750 kg ha^{-1} (T_3) recorded the earliest flowering (65.53 days). It was followed by the treatment of FYM@ 12.5 t ha^{-1} (T_2) which recorded 66.26 days. The delayed flowering (67.93 days) was observed in the control treatment (T_1).

4.2.2 Length of Pod (cm)

The observations on length of pod at harvest are presented in Table 10. All the treatments had significant influence on pod length. Among the treatments, application of EFYM@ 750 kg ha^{-1} (T_3) recorded 8.80 cm. The least pod length of 6.96 cm at harvest in the no organic manure application (T_1-control).

Table 6: Effect of Organic manures on Pod length (cm), number of pods plant^{-1}, number of seeds pod^{-1} and hundred seed weight (gram) of glori lily

Treatment details	Pod length (cm)	Number of pods plant^{-1}	Number of seeds pod^{-1}	Hundred seed weight (gram)
T_1	6.96	17.97	41.30	2.14
T_2	7.83	18.59	43.43	2.21
T_3	8.80	20.36	44.34	2.31
T_4	7.60	18.80	43.84	2.20
S.E$_D$ CD (p= 0.05)	0.52 0.52	0.44 0.63	0.28 0.40	0.04 0.06

4.3 Yield attributes

4.3.1 Number of pods plant^{-1}

The data recorded on the number of pods plant^{-1} at harvest are presented in Table 6. The treatments had significant influence on the number of pods plant^{-1}. Among the treatments, application of EFYM@750 kg ha^{-1} (T_3) was found to be significantly superior over other treatments. It recorded the highest number of pods plant^{-1} of 20.36 at harvest. Application of FYM @ 12.5 t ha^{-1} (T_2) was on par with pressmud application @ 5 t ha^{-1} (T_4). The lowest pod number of 17.97 at harvest was recorded in no organic manure application (T_1-control).

4.3.2 Number of seeds pod^{-1}

The data on number of seeds pod^{-1} are presented in Table 6. The treatments had significant influence on the number of seeds pod^{-1}. Among the treatments, application of EFYM@ 750 kg ha^{-1} (T_3) recorded the highest number of seeds pod^{-1} of 44.34. The least number of seeds pod^{-1} of 41.30 was recorded under no organic manure application (T_1-control).

4.3.3 Hundred Seed weight test weight (g)

The data on hundred seed weight (test weight) are presented in Table 6. The treatments had significant influence on the hundred seed weight. Among the treatments, application of EFYM @ 750 kg ha^{-1} (T_3) recorded the highest seed weight of 2.31 gm. The least hundred seed weight of 2.14 g was recorded by no organic manure application (T_1 - control).

4.3.4 Seed yield (kg ha^{-1})

The data on seed yield (kg ha^{-1}) are presented in Table 7. All the treatments had significant influence on seed yield. Among the treatments, application of EFYM @ 750 k ha^{-1} (T_3) recorded the highest seed yield of 686.34 kg ha^{-1}. The least seed yield of 529.25 kg ha^{-1} was recorded under no organic manure application (T_1-control).

Table 7: Effect of Organic manures on seed yield (kg ha^{-1}), Tuber yield (gram) and Fresh tuber yield (kg ha^{-1}) of glori lily

Treatment details	Seed yield (kg ha^{-1})	Tuber yield (gram)	Fresh tuber yield (kg ha^{-1})
T_1	529.25	127.06	1872.86
T_2	573.61	172.46	1949.37
T_3	686.34	207.20	2147.85
T_4	589.26	190.06	1968.91
S.E$_D$ CD (p = 0.05)	0.74 1.81	3.04 7.44	2.07 5.08

4.3.5 Fresh weight of tuber plant^{-1} (g)

The data on fresh weight of tuber recorded at harvest are presented in Table 7. All the treatments had significant influence on the fresh weight of tuber plant^{-1} (gm). Among the treatments, application of EFYM @ 750 kg ha^{-1} (T_3) recorded the highest tuber weight of 207.20 gm. The least fresh tuber weight of 127.06 g was recorded under the no organic manure application (T_1-control).

4.3.6 Fresh tuber yield (kg ha^{-1})

The data on fresh tuber yield (kg ha^{-1}) recorded at harvest are presented in Table 7. All the treatments had significant influence on fresh tuber yield. Among the treatments, application of EFYM @ 750 kg ha^{-1} (T_3) recorded the highest tuber yield of 2147.85 kg ha^{-1}. The least tuber yield of 1872.86 kg ha^{-1} was observed under no organic manure application (T_1-control).

4.4 Economics

The details on cost of cultivation, gross return ha^{-1}, net return ha^{-1} and return $rupee^{-1}$ invested for the crops are furnished in Table 10. The treatment of T_3 (EFYM@750 k ha^{-1}), performed better the other treatment and recorded the highest net return of Rs. 1288024.07 ha^{-1}. This treatment also recorded the return per rupee invested of Rs. 4.62. The treatment combination T_1 (no organic manure application-control), recorded the least net return of Rs. 660679.38 ha^{-1} and return per rupee invested of Rs. 3.20.

Table 10: Economic Analysis

Treatment	Seed yield (kg ha^{-1})	Tuber yield (kg ha^{-1})	Total cost of cultivation (Lakh Rs. ha^{-1})	Gross return (Lakh Rs. ha^{-1})	Net return (Lakh Rs. ha^{-1})	Return per rupee invested
T_1	373.00	1670.75	288145.62	948825	660679.38	3.20
T_2	731.41	2256.81	396109.67	1554735	1158625.33	3.92
T_3	791.28	2380.50	360061.93	1663686	1288024.07	4.62
T_4	745.56	2294.76	385447.90	1583100	1197652.10	4.10

(Cost of Tuber @ Rs. 300 kg^{-1}, Seed @ Rs. 1200 kg^{-1})

5. Discussion

Field experiment was carried out at the farmer's field, Devanur village, Ariyalur District of Tamil Nadu to study the effect of organic manures on the growth and yield of glori lily. Three organic sources were tested. The results of the experiment conducted are discussed in this chapter.

5.1 Growth characters

The results showed that application of organic nutrients favorably influenced all the crop growth characters. Among the treatments, application of EFYM @ 750 kg ha^{-1} (T_3) significantly influenced the growth characters viz., plant height, LAI, number of primary, secondary, tertiary branches $plant^{-1}$ and DMP. This might be due to higher availability of nutrients for the crop. Tolessa and Friesen (2001) [57] also reported that the EFYM besides having higher available NPK status had rich population of micro organisms might have degraded and mobilized the nutrients to available form.

Organic manures enriched with super phosphate increased the shoot and root ratio of maize by Sagare *et al*. (1986) [42]. Singh (1989) [50] explained that the enrichment of organic manures with mineral nutrients not only enhanced the rate of decomposition but also improved the nutrient status of the soil. Similar findings of increased plant height, tiller number, LAI and DMP due to enriched organic manure in rice crop was recorded. Marked improvement in the growth of rice viz., plant height, LAI, tiller number and DMP due to enriched manure application @ 750 kg ha^{-1} was reported by Sharma and Mitra (1991) [48].

The least growth components were reported under (T_1) no organic applied treatments. This might be due to reduced supply of nutrients through organic sources to the crop which restricted the growth of crop. Similar findings were also reported by Kumaraswamy *et al*. (1994) [25].

5.2 Flowering

In general, the present investigation showed that application of FYM @ 12.5 t ha^{-1}, EFYM @ 750 kg ha^{-1} and pressmud @ 5t ha^{-1} were found to hasten flowering in glori lily. The application of EFYM @ 750 kg ha^{-1} enhanced flower production and reduced the days taken to fifty per cent flowering. This might be due to the favorable effect of organic source nutrients. The result of present study was in close conformity with the findings of Darley Jose (1984) [13] in brinjal and Subbiah (1990) [54] in tomato.

5.3 Yield attributes and yield

Yield in general is a highly complex parameter influenced by the interaction of many factors or yield components and the ultimate goal of any crop management practices is to achieve increased yield. In glori lily, number of pods $plant^{-1}$, number of seeds pod^{-1}, seed yield and tuber yield were significantly increased by the use organic and inorganic nutrient sources.

Among the treatments, basal application of EFYM @ 750 kg ha^{-1} (T_3) attained superiority over others with regards to yield attributes viz., number of pods $plant^{-1}$, number of seeds pod^{-1} and hundred seed weight. Similar findings of increased yield attributes in rice crop were reported by Haque *et al.* (2007) [16].

5.4 Tuber yield

Tuber being the principal propagating material in gloriosa, has a commercial significance. Any treatment that would favorably alter the tuber size and yield will be advantageous in the farmers point of view. Among the treatments, basal application of EFYM @ 750 kg ha^{-1} (M_3) was found to enhance the tuber size and yield. Similar finding of increased rhizome yield in turmeric was reported by Haque *et al*. (2007) [16].

This might be due to better nutrition availability. Similar findings of increased turmeric yield due to application of enriched manure and inorganic fertilizers were reported by Senthilkumar *et al.* (2004) [46].

5.5 Economics

Application of EFYM @ 750 kg ha^{-1} (T_3) registered the highest net return of Rs. 1288024.07 and higher return $rupee^{-1}$ invested of Rs. 4.62, respectively. Application of pressmud @ 5t ha^{-1} (T_4) was found to be next in terms of net return and return $rupee^{-1}$ invested. Increased availability of nutrients with use of EFYM @ 750 kg ha^{-1} increased the crop growth characters, yield attributes, seed yield and tuber yield might be the reason for higher gross income, net income and BCR. Similar findings of higher net income and BCR due to use of EFYM and Inorganic in maize was reported by Tolessa and Friesen (2001) [57].

6. Summary and Conclusion

Field experiment was conducted at the farmer's field Devanur village, Ariyalur District of Tamil Nadu during 2008 to study the effect of organic manures on the growth and yield of glori lily. Three organic manures viz., control (T_1), FYM @ 12.5 t ha^{-1} (T_2), EFYM @ 750 kg ha^{-1} (T_3), and pressmud @ 5 t ha^{-1} (T_4) were tested. The treatments were replicated five adopting RBD design. The salient findings of the investigation are summarized below.

6.1 Growth parameters

Among the treatments, application of EFYM @ 750 kg ha^{-1} (T_3) recorded the highest value of growth components such as plant height (145.8, 181.1 and 207.8 cm), LAI (0.25, 0.57 and 0.64), number of primary branches (3.4, 4.0 and 3.7), number of secondary branches (12.3, 15.6 and 14.9) at 60, 90 and harvest respectively and dry mater production (12771.02 kg ha^{-1}) at harvest. The least values was recorded the under control treatment (T_1).

6.2 Flowering

Among the treatments, application of EFYM @ 750 kg ha^{-1} (T_3) recorded fifty per cent flowering in 65.53 days. No organic manures application control treatment (T_1) took 67.93 days to 50 per cent flowering.

6.3 Yield parameters

The yield components viz., number of pods $plant^{-1}$, number of seeds pod^{-1} and hundred seed weight were higher when soil application of EFYM @ 750 kg ha^{-1} (T_3) was recorded of 20.36, 44.34 and 2.31 at respectively. The yield components were reduced under no organic manure treatment (T_1).

6.4 Seed and tuber yield

With regard to treatments, basal application of EFYM @ 750 kg ha^{-1} (T_3) produced the highest seed yield of 686.34 kg ha^{-1}. Similar trend was recorded in case of tuber yield. The least seed and tuber yield was recorded under no organic manure application control (T_1).

6.5 Economics

In use of EFYM @ 750 kg ha^{-1} (T_3) recorded the highest return rupee^{-1} invested of Rs. 4.62 while the least return rupee^{-1} invested of Rs. 3.20 was observed in the treatment of no organic manure and inorganic application (T_1).

Conclusion

Based on the above results, it can be concluded that use of EFYM @ 750 kg ha^{-1} is found to be an appropriate agro-technique for augmenting the productivity and profitability of glori lily without affecting the soil fertility and soil health. Basal application of EFYM @ 750 kg ha^{-1} was recorded the highest value of growth components, fifty per cent flowering, yield components, highest seed and tuber yield were significantly increased.

References

1. Abubacker MN, Rao GR. Effect of Pressmud on rice. Journal of Indian Society of Soil Science. 1995; 43(2):300-302.
2. Amzad Hossain M, Yukio Ishimine. Effects of FYM on growth and yield of Turmeric (*Curuma longa* L.). Plant Production Science. 2007; 10(1):146-150.
3. Amzad Hossain MY, Ishimine S. Matsuura and Mitsuhiro Doi. Growth and Yield of Turmeric (*Curcuma* spp.) and Sweet bell Pepper (*Capsicum annum* L.) as influenced by Manda-compost, Japan., Science Bulletin., Faculty of Agriculture, University of Ryukyus. 2002; 49:205-212.
4. Balu S. Effect of Organic Manure Enriched Organic Manure and Flyash on Groundnut CV.VRI. 2: Laterile Soil. M.Sc. (Ag.) Thesis. Annamalai University, Annamalai Nagar, Tamil Nadu, India, 1993.
5. Bhat WN, Yadagourdar BA, Kundekar AR, Satyanarayana Rao S. Pressmud an alternative to FYM and green manuring in bidi tobacco cultivation. Tobacco Research. 1993; 19(2):111-113.

6. Biswas B. Gloriosa, In: Commercial Flowers, [eds.] Bose TK and Yadav LP, Nayaprakash, Calcutta, India, 1989.
7. Briajdar RR, Chalwade PB, Badole SB, Mangarge PS, Sheleage BS. Effect of Fly ash and FYM on nutrient availability in soil and yield of Sweet Potato. Journal of Soils and Crops. 2000; 10(2):248-251.
8. Carow BA Simple Estimation of Leaf Area. Deutscher Gartenbau. 1977; 31:10-16.
9. Cerna K. Effect of FYM and graduated ratio of mineral nutrients on yield formation in capsicum. Sbornik UVTIZ, Zahradnicttve. 1990; 7:297-307.
10. Chaudhuri PK, Thakur RS. 1,2-dimethyl colchicine a new alkaloid from *Gloriosa superba*. Journal of Natural Products. 1993; 56(7):1174-1176.
11. Chopra RN, Nayar SL, Chopra IC. Glosary of Indian medicinal plants, 1956, 125-126.
12. Cooke GW. Fertilizing for maximum yield. Third edition. Agricultural Research Council. Collins Professional and Technical Books, London, 1982.
13. Darley Jose. Studies on the efficacy of organic Vs. Inorganic form of N on brinjal (*Solanum melongena* L.) M.Sc. (Horti.) Thesis, Agriculture college & Research Institute, Madurai, 1984.
14. Dimri DC, Singh VP. Response of FYM, nitrogen and row spacing on bulb weight and yield of onion (*Allium cepa* L.) Cv. VI-3. Programme Horticulture. 2005; 37(1):185-187.
15. Ghosh B, Mukherjee M, Jha TB, Jha S. Enhanced colchicine production in root cultures of *Gloriosa superba* by direct and indirect precursors of the biosynthetic pathway. Biotechnology Letter. 2002; 24:234.
16. Haque MM, Rahman AKM, Ahmed M, Masul MM, Sarker MMR. Effect of nitrogen and potassium on the yield and quality of Turmeric in hillslope. International Journal of Sustainable Crop Production. 2007; 2(6):10-14.
17. Indira Raja M, Raj D. Influence of Pressmud application on yield and uptake of nutrient by finger millet in some soils of Tamil Nadu. Madras Agriculture Journal. 1981; 68(5):314-322.
18. Jackson ML. Soil chemical analysis. Prentice Hall of India Limited, New Delhi, 1973.
19. ------Nil.

20. Jain RC, Tiwari RJ, Chaudhari AK. Effect of insecticides and sugar pressmud on modulation yield, nutrient content and quality of soybean (*Glycine max* L.) Indian Journal of Agriculture Science. 1995; 65(1):20-23.

21. Kala SP. Processing and utilization of pressmud cake as a source of enriched manure. Ph.D., Thesis, Indian Agricultural Research Institute, New Delhi, India, 1981.

22. Kirthikar KR, Basu BD. Indian medicinal plants. M/s. Bishen Singh Mahendrapal Singh. Dehardun and M/s. Periodical Experts. New Delhi. 1975; 4:2225-2528.

23. Krishnamurthi VUP, Manickasundaram D, Tamilkani K, Vaiyapuriand P. Ganapamurthy. Role of digested coir pith, zinc and iron on the yield of turmeric. In the Abstract of National seminar on Emerging trends in horticulture, Annamalai University, 2002, 141.

24. Kumar M, Dinesh KS, Channabasappa, Patil SH. Effect of integrated application of pressmud and paddy husk with fertilizers on yield and quality of sugarcane (*Saccharum officinarum*). Indian Journal of Agronomy. 1996; 41(2):301-305.

25. Kumaraswamy BK, Bojappa KM, Faroogi A. Influence of the crop duration, fuel yield and its components in glori lily. Indian Journal of Forestry. 1994; 17(3):249-251.

26. Kuppuswamy G, Jayabal A, Lakshmanan AR. Effect of Enriched Biodigested Slurry and FYM on growth and yield of rice. Agriculture Science., Digest. 1992; 1(2):101-104.

27. Madhumita Das R, Singh BP, Muna Ram, Prasad N. Response of maize Meghalaya, Indian Journal of Agriculture Science. 1991; 61:383-388.

28. Meera Nair, Peter KV. Organic and inorganic fertilizer and their combinations on yield and storage life of hot chilli. Vegetable Science. 1990; 17(1):7-10.

29. Mohamed Amanullah M, Mohaned Yassin M, Vaiyapuri K, Somasundaram E, Satthyamoorthi K, Padmanathan PK. Inter cropping and organic manure on the growth and yield of cassava (*Manihot esculenta* crantz). Research Journal of Agriculture Biology Science. 2006; 2(4):200-206.

30. Nakamura J, Matsuura S, Hossian MA, Doimel M, Ishimine Y. Efficacy of manda 31 with fertilizer rates on growth and yield of turmeric

(*Curcuma* spp.). Science Bullatin. Faculty of Aauyrvedha University, Ryukyus. 2001; 48:145-152.

31. Nayak K. Effect of enriched farmyard manure and fertilizer levels on the growth and yield of finger millet (*Eleusine coracana Gaertn*). Under rainfed condition. Thesis submitted to university of agricultural Sciences, Bangalore, India, 1993.
32. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. United State Department of Agriculture, 1954, 929.
33. Pandita PN, Bhan MK. Effect of soil amendments on the yield of *Asparagus officinalis* L. Indian Journal of Plant Physiology. 1992; 35(3):262-264.
34. Panse VG, Sukhatme PV. Statistical method for agricultural workers. ICAR, New Delhi, India, 1978, 145.
35. Patil PV, Chalwade PB, Solanke AS, Kulkanni VK. Effect of fly ash and FYM on nutrient uptake and yield of onion Journal of Soils and Crops. 2005; 15(1):187-192.
36. ---------Nil.
37. Postma S. Application of animal manure on loess and Sandy soils. Verslag – Proegstation – voor – de – Akkerboaw – en – de – aioenitedt – in – de volleground. 1995; 197:111.
38. Prasad B, Singh RP. Accumulation and decline of available nutrients with long term use of fertilizers, manures and lime on multiple cropped Lands. Indian Journal of Agriculture Science. 1981; 51:108-111.
39. Ramesh Bedi. The Glory lily, Indian Horti. 1964; 8:9-10.
40. Rao R. Flowering Plants of Travancore. Govt. Press, Trivandrum, 1914, 415.
41. Rekhi RS, Benbi DK. Integrated use of organic manures and inorganic fertilizers, Progress. Fmg. 1999; 36(6):13-15.
42. Sagare BN, Guhe YS, Destimuku BA. Biological Yield and Uptake of Nutrients by Rice of influenced by enriched FYM product Journal of Maharashtra Agriculture University. 1986; 11:260-262.
43. Sarin YK, Reddy KL, Atal CK. Costus specious rhizome as source of diosgenin. Current. Science. 1974; 43:569-570.

44. Satyapal Singh, Balagan DS, Yaelar AC, Rana MK, Narendra Singh. Influence of FYM and gypsum in reducing the adverse effect of sodic water on attributes related to yield and quality of potato. Haryana Journal of Horticulture Science. 2002; 31(1-2):123-126.

45. Savithri P, Subbiah S, Malarvili P, Gopalsamy A. Effect of coir pith-based poultry litter on yield and nutrient uptake by sorghum coupea cropping system. In: proc. Seminar on utilization of coir pith in agriculture. TNAU, Coimbatore, 1991.

46. Senthil Kumar PS, Aruna Geetha S, Savithri P, Jagadeeswaran R, Ragunath KP. Effect of Zn enriched organic manure and zinc solubilizer application on the yield, curcumin content and nutrient status of soil under turmeric cultivation. Journal of Applied Horticulture. 2004; 6(2):82-86.

47. Shailendranath K, Rao KB. Influence of Pretreatment of fertilizers on nutrient availability of finger millet (*Eleusine coracana*) Mysore Journal of Agriculture Science. 1979; 13:405-480.

48. Sharma PB, Parashar RR, Ambawatia GR, Pillai PVA. Responsed Sesame Varieties Plant Population and Nitrogen Levels, Journal of Oil Seeds Research. 1996; 13(2):254-255.

49. Shindhu PH, Naik RL, Nazirkar RB, Kandam SK, Khaine VM. Evaluation of Vermicompost. Proceeding National Seminar. Organic Farming, 1992, 54-55.

50. Singh VP, Duhan SPS. Nitrogen and phosphorus fertilizer of *Mentha piperita* L. Tarai region of Nainital. Indian Perfumer. 1989; 25(1):82-83.

51. Sivakumar G, Krishnamurthy KV, Hahn EJ Pacuky. Enhanced *in vitro* production of Colchicine in *Gloriosa superba* L. an emerging industrial medicinal crop in South India. Journal of Horticulture Science. Biotechnol. 2004; 79(4):602-605.

52. Solaimalai A, Baskar M, Ramesh PT, Ravishankar N. Utilization of Pressmud as soil amendment and organic manures a review, Agriculture Revision. 2001; 22(1):25-32.

53. Srivastava JL, Pahapalkar MK. Cultivation traits on satawar *A. racemosus* in Mandla district in M.P. Vaniki Sandesh, 21(2), 24-23.

54. Subbiah K. Nitrogen and Azospirillum interaction on fruit yield and N use efficiency in tomato. South Indian Horticulture. 1990; 38(6):342-344.

55. Subramaniyan K, Wahab K. Effect of organic manure and fertilizer N on Post harvest soil nutrient status**.** Madras Agriculture Journal. 1997; 84(2):78-80.

56. Swarnapriya P, Doraipandian A, Arumugam T, Radha NS. Floral biology of *Gloriosa superba* L. South Indian Horticulture. 1995; 43(1-2):0-41.

57. Tolessa D, Friesen DK. Effect of enriching FYM with mineral fertilizer on grain yield of maize. Seventh Eastern and Southern Africa Regional maize conference, 2001, 335-337.

58. Tompe SV, More SD. Effect of pressmud cake on uptake of nutrients by sunflower. J Maharashtra Agriculture University. 1996; 21(1):139-140.

59. Walkley A, Black IA. An examination of Degtijareff method for determining the organic matter and proposed modification of the chromic acid titration method. Soil Science. 1934; 37:29-38.

60. Yadauvanshi NPS, Yadav DV. Effect of direct, residual and cumulative application of Pressmud with nitrogen on soil properties and on yield and quality of sugarcane, Indian Journal of Sugarcane Technology. 1992; 7(1):33-39.

61. Zdravkovi CM, Damjanovic M, Carokalo D. The influence of fertilization on the yield of different carrot varieties. Acta Horticulture. 1997; 462:93-9.

62. Standford S, English L. Use of flame photometer in rapid soil tests of K and Ca. Agronomy. Journal. 1949; 41:446-447.

63. ---------Nil.