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Intercropping of Fruit Crops with Winter Annual Flowers: A Sustainable and Profitable Orchard-Based Production System

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Subtropical fruit orchards offer substantial scope for intercropping due to wide spacing and delayed economic returns during the juvenile phase of fruit trees. Intercropping flowering winter annuals in these orchards is an efficient strategy to enhance land-use efficiency, farm income, soil health and ecological sustainability. The present article discusses the principles, suitability and management of flowering winter annuals such as marigold, calendula, annual chrysanthemum, lupin and acroclinium as intercrops in major subtropical fruit crops including mango, citrus, guava and strawberry. Emphasis is laid on crop compatibility, agronomic practices, economic advantages and ecological services. The article aims to provide scientifically sound yet farmer-friendly information for students, extension workers and orchard growers.

Key words: Intercropping, winter annuals, subtropical fruits, marigold, calendula, sustainable horticulture

Introduction

Intercropping is an important component of diversified and sustainable horticultural production systems, particularly in perennial fruit orchards where the main crop occupies the land for many years. In subtropical regions, fruit crops are generally planted at wide spacing to accommodate canopy expansion and long-term growth. These crops also require several years to reach full bearing, especially during the juvenile and early bearing stages. During this long establishment phase, a substantial portion of the orchard land, particularly the inter-row spaces, remains unused. As a result, valuable natural resources such as land, irrigation water, soil nutrients and solar radiation are not fully exploited, leading to low productivity per unit area and delayed economic returns to growers. Intercropping flowering winter annuals in subtropical fruit orchards offers an effective and practical solution to this problem by ensuring efficient utilization of these otherwise vacant interspaces. Winter annual flowers are ideally suited for intercropping because of their short growth duration, shallow and confined root systems, and relatively low nutrient and water requirements. Their growth cycle fits well within the winter season when competition from fruit trees is minimal, as perennial fruit crops generally exhibit reduced vegetative activity during this period. This complementary growth habit allows both the main fruit crop and the intercrop to co-exist without significant competition for resources. The integration of flowering winter annuals into fruit orchards provides multiple benefits beyond efficient land use. Economically, these crops generate quick returns and regular income during the non-bearing or low-yielding stages of fruit trees, thereby improving farm profitability and financial stability. Agronomically, flowering intercrops contribute organic residues to the soil, improve soil structure, enhance microbial

activity and reduce soil erosion by providing ground cover. Ecologically, they promote biodiversity by attracting pollinators and beneficial insects, creating a more balanced and resilient orchard ecosystem.

With the growing emphasis on integrated farming systems, resource conservation and sustainable intensification of agriculture, fruit–flower intercropping systems have gained considerable importance in subtropical horticulture. Such systems not only enhance productivity and profitability but also support environmental sustainability by improving resource-use efficiency and ecological balance. Consequently, intercropping flowering winter annuals in subtropical fruit orchards is increasingly being recognized as a viable and sustainable approach for optimizing orchard management and improving overall system performance.

Principles of Intercropping in Subtropical Fruit Orchards

The success of intercropping depends on the complementary use of growth resources by component crops. Subtropical fruit trees generally have deep and extensive root systems, while flowering winter annuals explore the upper soil layers. This vertical separation of root zones minimizes competition for nutrients and moisture. Similarly, fruit trees utilize vertical space through canopy development, whereas annual flowers efficiently occupy horizontal space between tree rows. Flowering intercrops also influence the orchard microclimate by reducing soil temperature fluctuations, suppressing weed growth and minimizing soil erosion. The presence of flowering plants attracts pollinators and beneficial insects, which contributes to improved ecosystem services within the orchard.

Suitability of Subtropical Fruit Orchards

Subtropical fruit orchards, in general, are well suited for intercropping with flowering winter annuals due to their wide spacing, perennial nature and extended juvenile phase. During the early years of orchard establishment, large inter-row spaces remain unutilized, providing ample opportunity for growing short-duration flowering crops. Even in bearing orchards, appropriate canopy management and regulated input use allow successful cultivation of winter annuals without adversely affecting fruit yield. Most subtropical fruit trees possess deep and extensive root systems, while winter annual flowers explore only the upper soil layers. This natural separation of root zones minimizes competition for nutrients and moisture. Additionally, fruit trees primarily utilize vertical space through canopy growth, whereas flowering annuals efficiently occupy horizontal space, ensuring complementary use of light and land resources.

Flowering Winter Annuals as Intercrops

Flowering winter annuals are considered ideal intercrops in subtropical fruit orchards because of their excellent adaptability to cool season conditions, short life cycle, rapid growth and consistent market demand. These crops establish quickly, complete their growth within a limited time span and make efficient use of available space and resources without causing significant competition to perennial fruit trees. Their shallow root systems confine nutrient and water uptake largely to the upper soil layers, making them highly compatible with deep-rooted fruit crops. In addition, flowering winter annuals provide early and assured economic returns, which is particularly beneficial during the non-bearing or low-yielding stages of fruit orchards.

Marigold (*Tagetes* spp.) is one of the most commonly grown flowering annuals as an intercrop due to its hardy nature, wide adaptability and high flower yield. It performs well under varied soil and climatic conditions and requires relatively low inputs. An important added advantage of marigold is its pest-repellent and nematode-suppressing properties, which help improve soil health and reduce pest incidence in orchard systems. Calendula (*Calendula officinalis*) is another valuable winter annual, known for its bright orange and yellow flowers, medicinal and cosmetic uses, and strong ability to attract pollinators and beneficial insects. Its cultivation enhances both economic returns and ecological balance within the orchard

ecosystem. Annual chrysanthemum is widely preferred for its attractive blooms and high demand in loose flower markets, particularly during the winter season and festive periods. It fits well into intercropping systems due to its moderate nutrient requirement and uniform growth habit. Lupin, a leguminous winter annual, plays a dual role as an intercrop by producing ornamental flowers while simultaneously enriching soil fertility through biological nitrogen fixation. Its inclusion improves soil nitrogen status and reduces dependence on synthetic fertilizers, contributing to sustainable nutrient management. Acroclinium is primarily grown for dry flower production and is valued for its excellent colour retention and decorative appeal. As an intercrop, it offers niche market opportunities and adds diversification to orchard-based farming systems. Collectively, these flowering winter annuals enhance the productivity, profitability and sustainability of subtropical fruit orchards when integrated through well-planned intercropping practices.

Agronomic Management Practices

Seed Sowing and Transplanting of Seedlings

Successful intercropping of flowering winter annuals in subtropical fruit orchards largely depends on proper seed sowing and careful transplanting of healthy seedlings. Seed sowing is generally carried out at the onset of the winter season, when temperatures are moderate and favourable for germination and early growth. Seeds of winter annuals are usually sown in well-prepared nursery beds, seed trays or pro-trays filled with a light, friable and well-drained growing medium. A mixture of garden soil, sand and well-decomposed organic manure or compost provides an ideal medium for uniform germination and healthy seedling development. Fine tilth of the nursery bed ensures proper seed–soil contact and facilitates easy emergence of seedlings. Seeds should be sown at shallow depth, as most flowering annuals require light or minimal soil cover for germination. After sowing, light irrigation is provided using a rose can or fine sprinkler to maintain adequate moisture without causing displacement of seeds. Regular but gentle watering is essential during the germination phase, as excess moisture may lead to damping-off and other fungal diseases. Partial shade during the initial stages protects young seedlings from harsh sunlight and temperature fluctuations. Under favourable conditions, seeds of most winter annuals germinate within 7–15 days, depending on the species.

Seedlings are generally ready for transplanting within 2 to 3 weeks after sowing, when they attain sufficient height and develop a healthy root system with 3–4 true leaves. Transplanting should be done during the cool hours of morning or evening to reduce transplanting shock. Prior to transplanting, seedlings are hardened by gradually reducing irrigation and exposing them to open field conditions. In fruit orchards, seedlings are transplanted in inter-row spaces while maintaining a safe distance from the tree basin to avoid root disturbance and competition. Adequate spacing is maintained to ensure proper air circulation, light interception and uniform growth. Light irrigation immediately after transplanting helps in quick establishment and recovery of seedlings.

Nutrient and Water Management

Integrated nutrient management is essential for the successful adoption of intercropping systems in subtropical fruit orchards, as it ensures adequate and efficient nutrient supply to both fruit trees and flowering winter annuals. Since, both components differ in their growth duration, nutrient uptake pattern and root distribution, nutrient management strategies must be carefully synchronized to avoid competition and nutrient imbalances. The use of organic manures such as farmyard manure, compost or vermicompost plays a crucial role in improving soil structure, enhancing water-holding capacity and increasing soil organic carbon. These organic inputs also stimulate microbial activity, which facilitates better nutrient availability and long-term soil fertility. Fertilizer application in intercropped orchards should be balanced and need-based, taking into account the nutrient requirements of both fruit trees and intercrops. Excessive application of fertilizers, particularly nitrogen, should be avoided as it may lead to luxuriant vegetative growth of intercrops and intensify competition with fruit trees. Placement of fertilizers in separate zones near the tree basins for fruit crops

and along intercrop rows for flowering annuals can help minimize competition and improve nutrient use efficiency. Adoption of soil testing-based fertilizer recommendations further enhance precision and sustainability in nutrient management.

Irrigation

Irrigation scheduling is another critical component of integrated management in fruit–flower intercropping systems. Adequate and timely irrigation is required to meet the moisture needs of flowering annuals, especially during critical stages such as germination, flowering and bud development. However, excess irrigation should be avoided to prevent waterlogging, nutrient leaching and adverse effects on fruit tree root health. Efficient irrigation methods such as drip or micro-sprinklers allow precise water application, ensuring optimal moisture availability for intercrops while maintaining the health and productivity of fruit trees. Proper integration of nutrient and water management practices ultimately enhances resource use efficiency and supports sustainable orchard production systems.

Weed, Pest and Disease Management

Flowering intercrops suppress weed growth by providing ground cover. They also attract beneficial insects such as pollinators and natural enemies of pests, thereby enhancing biological control. Regular monitoring is essential to prevent pest and disease outbreaks and integrated pest management practices should be adopted.

Seed Production

Seed production of flowering winter annuals is an important activity, particularly for maintaining a regular supply of quality planting material and for varietal improvement. Seed production is generally undertaken by selecting healthy, vigorous and true-to-type plants from the intercrop. Plants showing superior growth, uniform flowering and desirable flower characteristics are retained as mother plants. Roguing of off-type, weak or diseased plants is essential to maintain genetic purity and seed quality. Most winter annuals are predominantly cross-pollinated and natural pollinators play a major role in seed set. Proper isolation distance or spatial separation is maintained to avoid genetic contamination from other varieties. Cultural practices such as timely irrigation, balanced nutrition and protection from pests and diseases are essential to ensure good seed development. Flowers intended for seed production are allowed to mature fully on the plant. Harvesting is done when flower heads or seed capsules turn dry and show signs of physiological maturity.

After harvesting, seed heads are dried under shade to preserve viability. Seeds are then extracted manually, cleaned and graded to remove chaff and inert matter. Proper drying to safe moisture levels is essential to prevent fungal infection and loss of germination capacity. Clean and dried seeds are stored in moisture-proof containers under cool and dry conditions. Properly produced and stored seeds retain high viability and vigour, ensuring successful establishment of flowering winter annuals in intercropping systems during subsequent seasons.

Economic and Ecological Benefits

Intercropping of flowering winter annuals in subtropical fruit orchards plays a significant role in improving the economic viability and ecological sustainability of orchard-based production systems, particularly during the non-bearing or early bearing period of fruit crops. Perennial fruit trees require several years to reach full productive potential, during which orchard owners often face low or negligible income despite substantial investment in land preparation, planting, irrigation and maintenance. The cultivation of flowering winter annuals in the inter-row spaces during this phase provides an important supplementary source of income, helping to offset establishment costs and ensure regular cash flow. This additional income contributes directly to improved farm profitability and greater economic stability, especially for small and marginal growers who depend on timely returns for sustaining orchard operations. From an economic standpoint, flower intercrops significantly enhance benefit–cost ratios by increasing total output from the same unit of land. Since winter annuals are short-duration crops with relatively low input requirements, the cost of cultivation remains moderate while returns from flower sales are often attractive due to steady market

demand during the winter season. Intercropping also ensures better utilization of available resources such as land, irrigation water, nutrients and solar radiation, which would otherwise remain underused in young orchards. Efficient resource use leads to higher overall productivity and improved economic efficiency of the orchard system. Beyond economic benefits, intercropping flowering winter annuals contributes substantially to ecological sustainability. The presence of diverse flowering plants enhances on-farm biodiversity by attracting pollinators, natural enemies of pests and other beneficial organisms. This biological diversity supports natural pest regulation and reduces the dependence on chemical pesticides. Flower intercrops also provide ground cover, which helps in minimizing soil erosion, moderating soil temperature and conserving soil moisture. The addition of crop residues and root biomass improves soil structure, organic matter content and microbial activity, thereby enhancing long-term soil health.

Intercropping systems also help reduce reliance on chemical inputs by promoting natural nutrient cycling and biological processes. The inclusion of leguminous flowering annuals such as lupin is particularly beneficial, as these crops fix atmospheric nitrogen through symbiotic associations with soil microorganisms. This biological nitrogen fixation enriches soil fertility, reduces the need for synthetic nitrogen fertilizers and supports sustainable nutrient management. Overall, intercropping flowering winter annuals in subtropical fruit orchards represents a holistic approach that integrates economic gains with ecological benefits, making orchard systems more resilient, productive and sustainable in the long term.

Constraints and Precautions

Despite the numerous economic and ecological advantages, intercropping in subtropical fruit orchards requires careful planning and scientific management to avoid adverse effects on the main fruit crop. Improper selection of intercrops that are highly competitive for nutrients, water or light can lead to resource competition, resulting in poor growth and reduced yield of fruit trees. Similarly, dense planting of intercrops may restrict air circulation and light penetration, creating an unfavourable microclimate within the orchard that can increase the incidence of pests and diseases. Excessive or imbalanced application of fertilizers, particularly nitrogen, may promote vigorous growth of intercrops at the expense of fruit crops, further intensifying competition and affecting fruit quality. Operational challenges may also arise if intercropping is not properly planned. Dense or poorly arranged intercrops can interfere with routine orchard operations such as irrigation, spraying, pruning and harvesting. Mechanization becomes difficult when intercrops obstruct movement of machinery or labour within the orchard, increasing labour requirements and management costs. Additionally, inadequate separation between tree basins and intercrop rows may lead to disturbance of feeder roots and long-term negative effects on tree health. Therefore, the success of intercropping systems depends largely on the judicious selection and management of intercrops. Crops should be chosen based on local agro-climatic conditions, growth habit, rooting depth and compatibility with the main fruit crop. Market demand and economic viability of the intercrops should also be carefully evaluated to ensure profitability. Proper spacing, regulated input use and timely removal of intercrops after harvest are essential to maintain orchard productivity and sustainability. When these factors are carefully considered, intercropping can be practiced effectively without compromising fruit yield or orchard management efficiency.

Conclusion

Intercropping of flowering winter annuals in subtropical fruit orchards is a scientifically sound and economically viable practice. When properly planned and managed, this system ensures efficient utilization of land and resources, enhances farm income, improves soil health and promotes ecological balance. Adoption of fruit–flower intercropping systems can play a significant role in sustainable intensification of subtropical horticulture and should be encouraged through research, extension and farmer participatory approaches.