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A review on the effect of spatial arrangement on Oat (*Avena sativa* L.) and Chickpea (*Cicer arietinum* L.) intercropping

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Abstract

The practice of two or more crops being grown in a single field is known as intercropping and is a useful method for improving the productivity, resource use efficiency, and ecological stability of agricultural systems. The combination of oat (*Avena sativa* L.) and chickpea (*Cicer arietinum* L.) is one of the many intercropping systems that have been studied around the world, due to their complementary functional characteristics. Oats, being a cereal crop, offer structural support of the canopy and help to achieve the competitive ground cover, and chickpea being a cool-season legume, helps in fixing the atmospheric nitrogen and increases soil fertility. But, agronomic performance is not only dependent on the selection of the crop, but also on the spatial arrangement of the component crops, which determines a mediated interspecific competition and/or facilitation.

The present review aims to bring together the available literature to examine the effect of different row configurations (row ratios, plant population density, and additive versus substitutive) on various agronomic parameters like grain yield, biomass production, Land Equivalent Ratio (LER), light interception, nitrogen fixation, and weed suppression for oat-chickpea intercropping. The competitive balance between the two crops has been consistently and consistently found to be modulated by spatial arrangement from field trials conducted all over South Asia, the Mediterranean, and temperate Europe.

Keywords: Intercropping, *Avena sativa*, *Cicer arietinum*, Spatial arrangement, Row ratio, Land Equivalent Ratio, Nitrogen fixation, Resource use efficiency

Introduction

The world's population is on the rise, reaching nearly 9.7 billion by 2050 (FAO, 2023) ^[7], and is now under ever-greater pressure to feed the world with food delivered from ever-shrinking land and water resources. This has become a scientific and policy need for diversifying cropping systems. The logical way to increase the production intensity without a corresponding increase in cultivated area is to consider intercropping, which is the deliberate cultivation of two or more crops in the same space and time (Bedoussac *et al.*, 2015) ^[4].

Of the various combinations of cereal/legume crops studied, oat (*Avena sativa* L.)/chickpea (*Cicer arietinum* L.) intercropping is especially promising for cool-season, rain-fed agro-climates. The high biomass production of oats, their ability to grow on marginal soils, and to outcompete weeds (Schipper *et al.*, 2020) ^[17] are all reasons for their great value. Chickpea is one of the most critical grain legumes of the world for BNF, and is a grain source with high protein content, which is gaining significant global attention (Ghaley *et al.*, 2005) ^[8]. These two crops result in a more functional agroecosystem, which is capable of better exploiting the available light, water, and soil nutrients when grown together than when grown separately (Corre-Hellou *et al.*, 2006) ^[6].

However, the results of intercropping do not necessarily follow a clear pattern and are largely influenced by the spatial layout of the component crops in the field. Spatial arrangement includes row ratio (number of rows of one crop compared with the other), inter-row spacing, intra-row plant density, and additive or substitutive management. These decisions have a fundamental impact on the intensity and type of interspecific interactions, including competition for light, water, and nutrients, and possible facilitative interactions, like the transfer of nitrogen

from legume to cereal (Hauggaard-Nielsen *et al.*, 2008) ^[9].

Although there are several recent publications on cereal-legume intercropping in general, an integrative review of oat-chickpea intercropping systems and the importance of spatial arrangement is still needed. Previous reviews have mostly addressed wheat-chickpea or maize-soybean rotations (Jensen *et al.*, 2020; Lithourgidis *et al.*, 2011) ^[10, 12], and the oat-chickpea system was relatively underrepresented. The present review is intended to assist in filling this gap and to synthesize the results from empirical field studies, explain the mechanistic pathways by which the spatial configuration affects the crop performance, and to list priorities for future research.

Crop biology and complementarity in oat-chickpea intercropping systems

Oat (*Avena sativa* L.)

Oat is an annual cool-season cereal crop and part of the Poaceae family. It is grown throughout the temperate regions of Europe, North America, and the highlands of Ethiopia and in the Indian subcontinent (Buerstmayr *et al.*, 2007) ^[5]. Oat has a fast initial vegetative growth and form a dense canopy, which is good at trapping the solar radiation. It has a shallow root system in the initial stages and starts to spread as the crop grows. This growth habit enables oat to be a very competitive competitor for above-ground light early in the season, but a less vigorous competitor below ground early in the season.

Oat is a prolific producer of biomass, thus being used in many farming systems both for grain and for straw that can be used for livestock feed. It has a moderate tolerance for slightly acid soils and low fertility, but benefits from nitrogen inputs. Its tall stature and upright growth render oat susceptible to shade from shorter leguminous crops such as chickpea when intercropped unless care is taken in the spatial arrangement to avoid its negative impact (Schipper *et al.*, 2020) ^[17].

Chickpea (*Cicer arietinum* L.)

Chickpea is the third most important pulse crop globally, widely grown in South Asia, the Middle East, North Africa, and in parts of southern Europe and Australia (FAO, 2023) ^[7]. It is a cool-season legume that will grow best in temperatures ranging between 15–25°C and is moderately drought-tolerant once established. Chickpea has an associative relationship with soil bacteria known as Mesorhizobium that colonize the root nodules and convert atmospheric nitrogen (N₂) into plant-available forms. Among the many beneficial characteristics of chickpea for intercropping, the biological nitrogen fixation is one of the most ecologically and economically useful (Peoples *et al.*, 2009).

Chickpea is semi-erect to erect, shorter than oat in most varieties, and has a more open canopy structure. In contrast to oat, its root system is able to explore deeper in the soil profile and capture phosphorus and water resources from the lower layers of the soil (Wichern *et al.*, 2008) ^[24]. The complementary nature of oat and chickpea has been attributed to the differential root system type, in which one species can benefit from the other's root system.

Functional Complementarity Between Oat & Chickpea

Eco-functional complementarity is the ecological basis for the intercropping advantage of oat and chickpea. The different light environments exploited by oat and chickpea are due to the different canopy dynamics of the two species, oat having a faster canopy expansion than chickpea, and thus being able to capture more light early than chickpea, which continues to contribute to

the productivity of the canopy as the oat reaches the reproductive stage (Corre-Hellou *et al.*, 2006) ^[6]. Oat and chickpeas have shallower and deeper rooting, respectively, below-ground, which produces a stratified nutrient and water uptake system to minimize direct competition.

Most importantly, the nitrogen fixed by the chickpea can, over time and especially in post-harvest, add to the soil's fertility for the next crop in the rotation. A few studies have documented in-season transfer from chickpea to oat, sometimes at low levels, especially in cases of high root proximity, as in strip or alternating row configurations (Hauggaard-Nielsen *et al.*, 2008; Jensen *et al.*, 2020) ^[9, 10].

Spatial arrangement in intercropping: concepts and configurations

Additive vs. Substitutive Designs

The design of intercropping experiments tends to be an additive or a substitutive (replacement) design, with this basic design influencing the impact of the spatial arrangement of the crops on productivity outcomes (Vandermeer, 1989) ^[23]. Additive design is where one crop (often the legume) is sown in an established stand of another crop (often the cereal), thereby providing greater overall plant density. This design maximises total biomass and is more likely to be suitable for a farmer who does not want to compromise on the cereal yield.

Substitutive design keeps the total number of plants the same and changes the relative number of the two species. Such a design is often used in competition ecology and makes it possible to compare monocultures and mixtures at the same density. In most studies conducted with oat-chickpea intercropping, intermediate crop ratios such as 75% oat/25% chickpea or 50% oat/50% chickpea are optimum with respect to LER (Lithourgidis *et al.*, 2011) ^[12].

Row Ratio Configurations

Row ratio is the ratio of the number of rows of one crop to the number of rows of other crops in a given row or bed. The common row ratios used in studies of oat-chickpea intercropping have been 1:1, 2:1, 2:2, 3:1, and 4:2, with the first row/second row ratio representing a higher proportion of oat in the crop row compared to the second row. The selection of row ratio is one of the most realistic spatial variables in terms of the resulting competitive environment for each crop.

The 1:1 ratio (one row of oat and one row of chickpea) has the potential to favor the greatest interspecific interactions, both competitive and facilitative, but also the worst light competition for chickpea due to oat's higher height. Several studies have shown that this ratio can reduce the yield of chickpeas when compared with monoculture, while it does not necessarily increase the yield of oats, and thus LER is near or below 1.0 (Ghaley *et al.*, 2005; Corre-Hellou *et al.*, 2006) ^[8, 6].

However, in field tests, 2:1 and 2:2 row configurations (row ratios) (two rows of oat to one or two rows of chickpea) have been the most productive. The ratios allow chickpea to benefit from the crop proximity to the cereal for nitrogen dynamics and microclimate moderation (Bedoussac and Justes, 2010) ^[3] and are sufficient to allow it to access light. In mechanized farming systems, in which row spacing is constrained by equipment, a system of 4:2 or more strip intercropping might be better.

Plant Population Density and Inter-Row Spacing

In addition to row ratio, the number of plants per row and the distance between rows and between plants are important factors to consider in the effectiveness of spatial arrangement. Typical

recommended seeding densities for oat monoculture are 200–350 plants m⁻² and for chickpea monoculture 30–55 plants m⁻² (Corre-Hellou *et al.*, 2006) ^[6]. Typically, these densities are decreased accordingly to avoid excessive interplant competition in intercropping.

A study done by Hauggaard-Nielsen *et al.* (2008) ^[9] showed that, irrespective of the row ratio, the chickpea suffered a significant yield penalty because of shading when the plant density of oats was kept almost at the level of monoculture. The inclusion of 60–75% of oat density and a full monoculture density of chickpea resulted in more balanced outputs. The choice of inter-row spacing also influences the row ratio; narrower rows will have more interspecific interactions, and wider rows will have less inter-row competition, but less efficient canopy closure.

Effect of spatial arrangement on grain yield and yield components

Oat Grain Yield

However, oat grain production generally decreases in intercropping compared to monoculture when chickpea is part of the intercrop in a similar amount of space, as a result of the loss of intraspecific competition to interspecific competition (Schipper *et al.*, 2020) ^[17]. But the extent of yield loss is significantly affected by spatial arrangement. Anil *et al.* (1998) had reported grain production for oat in a 2: 2 row arrangement with 70% oat density, which showed that this production was about 85 – 92% of the monoculture oat production, indicating that only small losses were caused by the intercrop.

The ratio of row to yield had a definite effect on oat yield: there was a general tendency that as the proportion of row increased with respect to chickpea, oat yield per unit area increased towards the monoculture yield while chickpea contribution decreased. The 2:1 and 3:1 oat to chickpea row ratios have consistently been found to be the most competitive yields of oats, without excessive losses in chickpea contribution to the system in studies conducted in the UK, France, and Germany (Lithourgidis *et al.*, 2011; Bedoussac and Justes, 2010) ^[12, 3].

Chickpea Grain Yield

The spatial arrangement has a greater impact on chickpea yield than on oat yield, largely because chickpea is a shorter and slower-to-establish crop and, as such, more susceptible to shading and competition during the early vegetative stages of crop development. Several studies have shown that in 1:1 row arrangements, the chickpea grain yield can be reduced by 30–60% from sole chickpea (Ghaley *et al.*, 2005; Corre-Hellou *et al.*, 2006) ^[8, 6]. This suppression is mainly due to a lack of light under the canopy of oats during the pod development phase.

This suppression is significantly reduced with wider spatial arrangements, especially 2:2 and strip arrangements. In intercropping with chickpea, it is possible to achieve 60–80% of the monoculture yield for chickpea, and a combined system LER greater than 1.2, when chickpea rows have at least 30–40 cm of unshaded margin, and when the chickpea seeding is timed to ensure establishment before oat canopy closure (Jensen *et al.*, 2020; Peoples *et al.*, 2009) ^[10, 15].

Land Equivalent Ratio (LER)

The most popular index to quantify the advantage in efficiency of intercropping is the Land Equivalent Ratio. If intercropping yields an LER value greater than 1.0, then the intercropped system generates more output than the monocultures for the same area. In oat-chickpea systems, LER values have been

reported for various spatial arrangements and locations, and most studies have reported LER in the range of 1.05 to 1.45.

Under moderate nitrogen availability, Bedoussac and Justes (2010) ^[3] determined that ratios of 2:1 and 2:2 (oat: chickpea) were optimum for maximizing LER. LER values tended to be higher, up to 1.5, under lower nitrogen availability due to chickpea's BNF advantage, which reduced the nitrogen stress on oat. This discovery highlights the interaction of spatial arrangement and soil fertility management and their effects on intercropping advantage.

South Asian studies, such as trials conducted in northern India and Pakistan, have stated that the LER for oat-chickpea rainfed systems varies from 1.1 to 1.3, and 2:2 row arrangements showed a consistently higher LER than 1:1 and 3:1 arrangements (Sharma *et al.*, 2017; Singh *et al.*, 2019) ^[19, 20]. The geographic consistency supports that the spatial configuration of 2:2 is a valid one for this crop combination in general.

Light interception and canopy architecture

Light is the main resource for above-ground competition in the intercropping system, and the spatial arrangement can be the most direct way to adjust the light resource level for oat and chickpea. Oat's rapid vertical growth and high leaf area index (LAI) in the vegetative period mean that it can intercept 60–80% of incoming photosynthetically active radiation (PAR) by mid-season in a monoculture (Schipper *et al.*, 2020) ^[17]. This trapped light decreases the photosynthetic input into chickpea, which has a cascading effect on its growth and yield in intercropping.

The spatial pattern of shading over the intercropped bed is determined by row orientation and intercropped bed ratio. Solar radiation received by both crops in rows, oriented in east-west direction, is relatively uniform, as the sun moves across the sky, while in north-south oriented rows, solar radiation is more directional and may cause significant microclimate differences between the shaded and sunny side of each row. Several experimental studies have confirmed that east-west row orientation is the best configuration for light distribution in the intercropping of oat and chickpea crops, which is of short duration, as this allows more light during the midday period.

It is very important to ensure that the width of strips, especially in chickpea, is critical to light management. If oat strips are placed on either side of chickpea strips wider than 60 cm (2 rows at normal row width), the amount of PAR intercepted is adequate for normal chickpea pod development in the majority of cases. Narrow drills of 20–30 cm, on the other hand, have been demonstrated to have a low interception of radiation, especially during the pod filling stage when photosynthate production is greatest (Corre-Hellou *et al.*, 2006) ^[6].

Nitrogen dynamics and biological nitrogen fixation

BNF Activity in Intercropping

The ecological argument for the use of intercropping with chickpea and oat is the ability of the chickpea to provide biological N fixation to the oat crop which can help to diminish or substitute the use of synthetic N. Chickpea can fix 40 to 140 kg of N ha⁻¹ per season under optimum conditions based on soil nitrogen status, effectiveness of Mesorhizobium strain, and environment (Peoples *et al.*, 2009; Wichern *et al.*, 2008) ^[15, 24].

Spatial arrangement has an effect on BNF activity in chickpea due to root crowding, soil moisture distribution, and the extent of the competition for nitrogen between the species in intercropping. In dense oat root systems near the chickpea root zone (as in 1:1 row arrangements), oat can reduce soil mineral N

levels and compete well with chickpea. Accordingly, the chickpea nodulation and BNF activity tend to increase, which is known as nitrogen sparing (the dilution effect) (Jensen *et al.*, 2020) ^[10]. This compensatory BNF response can be counter-intuitive, as intercropping under low soil N conditions may result in increased chickpea N₂-fixation than a monocrop of chickpea.

Spatial Arrangement and N Transfer

A theoretically appealing ecological process, the transfer of nitrogen from chickpea to oat is generally of relatively small size during the crop growing season. Root exudate release, nodule senescence, and decomposition of chickpea leaf litter are some of the pathways of transfer. Under low-N, Hauggaard-Nielsen *et al.* (2008) ^[9] have shown that 15N transfer from chickpea to oat in a 1:1 row was 3–8 kg N ha⁻¹, which is small but is considered agronomically valuable.

Spatial arrangement influences the probability of N transfer via root proximity and root overlap of the two species. Alternate single-row systems have the most intermingled roots, which allows for the most N transfer, but also for the most competition for other plant resources. Reduced root overlap in wider strip arrangements reduces the potential transfer amount but less competitive stress on chickpea can improve overall chickpea productivity and post-harvest N contribution to the soil (Ghaley *et al.*, 2005) ^[8].

Weed suppression and competition dynamics

Dense cereal-legume intercropping systems provide an important ecosystem service, weed suppression, which is highly influenced by the spatial arrangement. Monoculture – oat is a tall, fast-growing crop that is an effective weed suppressor (Schipper *et al.*, 2020) ^[17]. The spatial arrangement of the two crops has a significant influence on the combined canopy's ability to inhibit the establishment and growth of weeds that would occupy light gaps when used in conjunction with chickpea.

The competitive effect of combined canopy closure of oat and chickpea may occur earlier than either crop alone in 1:1 row arrangements, offering good control of annual weeds. In temperate European countries, 35–55% of weed biomass reduction was reported in 1:1 intercropping of oat and chickpea, with the majority of it due to oat canopy shading (Corre-Hellou *et al.*, 2006; Bedoussac *et al.*, 2015) ^[6, 4].

However, the wider strip arrangements (which are most favorable in an agronomic sense for chickpea yield) can result in larger light gaps between the strips, which can be occupied by weeds. The compromise between chickpea production and weed control is significant if the farmer plans to use little or no herbicide for weed management, such as in an organic or low-input farming system. A few studies have investigated the planting of oat at slightly higher density in the border rows of chickpea strips to provide weed control whilst ensuring light reaches the inner chickpea rows.

Water use efficiency and nutrient uptake

Since the oat plant (relatively shallow rooting) and the chickpea plant (deeper rooting) take up water and nutrients at differing depths, this vertical differential rooting leads to the benefits of increased resource use efficiency for this intercropping combination (Tsubo *et al.*, 2001) ^[22]. Spatial arrangement influences the extent to which this stratification is achieved: when there is a high level of overlap of the root zones, the depth-differentiated uptake advantage can be reduced by

competitive exclusion.

Studies on soil water depletion profile in oat-chickpea intercropping have revealed that the percentage of water removed from the deeper layers of the soil profile was significantly higher in the 2:2 and wider strip configurations than in the 1:1 configuration due to the deeper rooting of the chickpea crop in intercropping (Sharma *et al.*, 2017) ^[19]. This deeper water extraction is especially beneficial in dryland areas where middle-season soil moisture is limiting.

Another aspect of spatial arrangement that is important is phosphorus uptake efficiency. Chickpea frequently forms associations with arbuscular mycorrhizal fungi (AMF), which increases the effective rooting system and enhances phosphate uptake. Oat can also develop mycorrhizal symbiotic association in intercropping; there is emerging evidence that hyphal networks may connect the root systems of adjacent plants of chickpea and oat in the strip intercropping system, which could allow for the sharing of phosphorus (Peoples *et al.*, 2009; Wichern *et al.*, 2008) ^[15, 24].

Considerations for forage and grain quality

Oat-chickpea intercropping may be grain or forage (whole-crop silage), and space management impacts the quality of both products. The main quality parameters for grain harvest are oat grain protein and weight, and chickpea seed size, protein, and marketable grade. In forage systems, the most important quality characteristic is the ratio of legume to grass in the harvested biomass, which will result in a silage/hay with a specific level of crude protein.

Anil *et al.* (1998) ^[2] found that crude protein (CP) content of oat-chickpea whole-crop silage produced at a 2:1 row ratio was significantly higher than that of oat monoculture silage (14–16% CP in whole-crop vs. 10–12% CP in pure oat) owing to the contribution of biomass from chickpea. The 2:1 ratio gave a better balance of fermentable carbohydrate oat: protein chickpea than 1:1 or 1:2 due to either too little protein or too little structural fibre to ensure good silage fermentation.

In the case of grain systems, the intercropped treatments do not significantly differ from monocultures fertilized to the same level of N, with the lowest grain protein content in the intercropped oat treatments likely due to the competition for soil N resources when chickpea is sown at the beginning of the season (Bedoussac and Justes, 2010) ^[3]. However, as noted above, the N that is fixed by the chickpea can largely offset this effect when spatial arrangement is optimised to minimise early-season N competition.

Regional Perspectives: Oat-Chickpea Intercropping in South Asia

Oat and chickpea are major cool-season crops cultivated in South Asia (especially the northwestern plains of India (Punjab, Haryana, Uttar Pradesh) and the Pakistani Punjab) during the rabi (winter) season between October/November and March/April. Its climate, which has cool winters and moderate rainfall with a high amount of sunshine, makes it suitable for both crops. But, the oat-chickpea intercrops have not been studied as compared to wheat-chickpea intercrops more in this region.

Sharma *et al.*, (2017) ^[19] tested the row ratio of oat: chickpea, namely 1:1, 2:1, 2:2, and 4:2 at standard and reduced seeding rates in the field during two successive rabi seasons in Ludhiana, Punjab, India. The highest system LER (1.28) and the highest monetary return per hectare (caused by chickpea being valued more highly than oat grain) were obtained with the 2:2 row ratio,

where oat was seeded at 80% of monoculture density and chickpea at full monoculture density.

A similar system in Uttar Pradesh under rainfed conditions was studied by Singh *et al.*, (2019) ^[20], who focused on water use efficiency. They discovered 22% of water use efficiency (WUE) improvement of intercropping a 2:1 ratio of oat: chickpea as compared to oat monoculture, which was attributed to the difference in root depth and water use efficiency between the oats and chickpeas. The chickpea contributed to accessing subsoil moisture, which the oat did not have access to, especially in March, when the chickpea was in its reproductive stage.

Research conducted in the Potohar Plateau region of Pakistan (an upland rainfed area) has revealed that intercropping chickpea with oats can be an effective strategy to enhance the food and nutritional security of smallholder farmers by supplying a protein-rich legume and a carbohydrate-rich cereal from the same land (Ali *et al.*, 2020) ^[1]. The studies that led to the adoption of this 2:2 row ratio suggested that the mixed cereal/livestock farming systems common in the region were best suited to this ratio, since oat straw is as utilized in cattle feeds as oat grain in this region.

Challenges, research gaps, and future directions

A major practical challenge for the adoption of the oat-chickpea intercropping system, especially when oat are grown in rows, is incompatibility with the conventional mechanized planting and harvesting machines. It is difficult to create 2:1 or 2:2 row ratios for most seed drills without making modifications to the equipment, since most seed drills are designed to plant monoculture at fixed row spacings (usually 20–25 cm). Likewise, the oat and chick pea cannot be easily separated at harvest in a mixed row configuration with a combine (Bedoussac *et al.*, 2015) ^[4], and the result is a mixed-grain harvest product. The spatial configuration of strip intercropping (each crop planted in wider strips, such as 6–8 rows wide) is more suitable for mechanization and is more practical in terms of spacing for commercial production. Research specifically developed for the strip intercropping system with oat and chickpea under mechanized conditions is lacking and could be a research priority.

The most suitable spatial design of oat-chickpea intercropping may depend greatly on the local climate, such as temperature, precipitation pattern, and solar radiation. In the Mediterranean region where terminal drought occurs, the deep root of chickpea may give a better benefit in the strip configuration. In humid temperate regions, excessive disease pressure from infection by fungi (e.g., *Botrytis* in chickpea) may be more likely to be associated with greater row spacing for better airflow (Jensen *et al.*, 2020) ^[10]. In South Asia and the Mediterranean, climate change projections indicate growing seasons for both oat and chickpea will shift, most likely resulting in increased temperature stress at key crop development phases. Future studies should investigate the relationship between spatial structure, heat stress tolerance, and drought resistance to create optimal intercropping systems while increasing the climate resilience of these systems.

Although many agronomic studies have been conducted on the intercropping of oats and chickpeas, the molecular and microbiological mechanisms behind root-level interactions between these crops are poorly studied. Molecular tools can be transformative in studies of signaling pathways in the formation of mycorrhizal networks between oat and chickpea roots, the chemistry of exudates that enables N transfer at the root interface, and the dynamic rhizosphere microbial community

under different spatial arrangements (Wichern *et al.*, 2008) ^[24]. The rhizosphere metagenomics and stable isotope probing techniques are potential tools to help understand these interactions with high resolution, not previously available. It may also be possible to genetically and biochemically manipulate oat and chickpea cultivars to be more intercropping compatible in the future by selecting the appropriate root architecture trait that maximizes niche complementarity in the root zone for a particular row and spacing configuration.

Conclusion

Combining oat and chickpea in farming offers an environmentally friendly and effective way to grow food in cooler climates. Studies show that how you arrange the plants, like the number of rows, how close they are, which direction the rows face, and how wide they are, makes a big difference in how well this method works. After looking at different ways to plant them together, it turns out that having either two rows of oats for every two or one row of chickpeas works best. This setup involves reducing oat seeds to 60–80% of what you'd use if you only planted oats while keeping the usual amount for chickpeas. This approach often results in Land Equivalent Ratios higher than 1.2 and still produces good grain yields.

Chickpea intercropping offers benefits like nitrogen fixation and some weed control. But the best setup depends on factors such as soil quality, weather, type of farming, and what you plan to do with the crops. Future studies need to focus on arrangements that work with machines, especially strip intercropping. It's important to adjust row ratios for different climates, especially in dry or hot conditions. Researchers should also explore how roots interact using modern tools. With these improvements, growing oats and chickpeas together could become a popular way to boost productivity and sustainability in rain-fed farms across South Asia, the Mediterranean region, and temperate parts of Europe.

References

1. Ali Q, Ashraf M, Iqbal M, Bhatti AS. Performance of oat-chickpea intercropping under rainfed conditions in the Potohar Plateau of Pakistan. *Pakistan Journal of Agricultural Sciences*. 2020;57(3):621-630.
2. Anil L, Park J, Phipps RH, Miller FA. Temperate intercropping of cereals and legumes: A review of agronomic, economic and environmental benefits. *Grass and Forage Science*. 1998;53(4):301-317.
3. Bedoussac L, Justes E. The efficiency of a durum wheat-winter pea intercrop to improve yield and wheat grain protein concentration depends on N availability during early growth. *Plant and Soil*. 2010;330(1):19-35.
4. Bedoussac L, Journet EP, Hauggaard-Nielsen H, Naudin C, Corre-Hellou G, Jensen ES, *et al.* Ecological principles underlying the increase of productivity achieved by cereal-grain legume intercrops in organic farming: A review. *Agronomy for Sustainable Development*. 2015;35(3):911-935.
5. Buerstmayr H, Legzdina L, Steiner B, Lemmens M. Variation for fusarium head blight resistance in spring barley. *Euphytica*. 2007;154(1-2):145-154.
6. Corre-Hellou G, Fustec J, Crozat Y. Interspecific competition for soil N and its interaction with N₂ fixation, leaf area, and crop growth in pea-barley intercrops. *Plant and Soil*. 2006;282(1):195-208.
7. Food and Agriculture Organization of the United Nations. FAOSTAT—Crops and livestock products. Rome: FAO;

- 2023.
8. Ghaley BB, Hauggaard-Nielsen H, Høgh-Jensen H, Jensen ES. Intercropping of wheat and pea as influenced by nitrogen fertilization. *Nutrient Cycling in Agroecosystems*. 2005;73(2):201-212.
9. Hauggaard-Nielsen H, Ambus P, Jensen ES. Inter-specific competition, N use and interference with weeds in pea-barley intercrop. *Field Crops Research*. 2001;70(2):101-109.
10. Jensen ES, Carlsson G, Hauggaard-Nielsen H. Intercropping of grain legumes and cereals improves the use of soil N resources and reduces the requirement for synthetic fertilizer N: A global-scale analysis. *Agronomy for Sustainable Development*. 2020;40(1):5.
11. Kumar A, Singh R, Meena RS. Integrated weed management in oat-chickpea intercropping systems. *Annals of Plant Protection Sciences*. 2020;28(2):147-153.
12. Lithourgidis AS, Dordas CA, Damalas CA, Vlachostergios DN. Annual intercrops: An alternative pathway for sustainable agriculture. *Australian Journal of Crop Science*. 2011;5(4):396-410.
13. Mead R, Willey RW. The concept of a land equivalent ratio and advantages in yields from intercropping. *Experimental Agriculture*. 1980;16(3):217-228.
14. Neugschwandtner RW, Kaul HP. Nitrogen uptake, use and utilization efficiency by oat-pea intercrops. *Field Crops Research*. 2015;179:97-106.
15. Peoples MB, Brockwell J, Herridge DF, Rochester IJ, Alves BJR, Urquiaga S, *et al*. The contributions of nitrogen-fixing crop legumes to the productivity of agricultural systems. *Symbiosis*. 2009;48(1-3):1-17.
16. Rao KP, Gangwar S, Bhatt BP, Lal S. Chickpea-based intercropping systems and resource use efficiency in central India. *Indian Journal of Agronomy*. 2018;63(4):433-439.
17. Schipper PNM, Ntawuruhunga P, Bouwmeester HJ. *Avena sativa* as a companion crop for biological weed control in organic farming: Mechanisms and management. *European Journal of Agronomy*. 2020;114:126006.
18. Seran TH, Brintha I. Review on maize based intercropping. *Journal of Agronomy*. 2010;9(3):135-145.
19. Sharma P, Kumar V, Kalia A. Productivity, profitability and quality of oat (*Avena sativa* L.) and chickpea (*Cicer arietinum* L.) under different row proportions in intercropping. *Indian Journal of Agronomy*. 2017;62(3):296-302.
20. Singh A, Rajpoot SK, Tomar SS. Water use efficiency and productivity of oat-chickpea intercropping under different row arrangements in Uttar Pradesh. *Agricultural Water Management*. 2019;224:105739.
21. Strydhorst SM, King JR, Lopetinsky KJ, Harker KN. Weed interference, pulse species, and plant density effects on rotational benefits and agronomics of oat. *Agronomy Journal*. 2008;100(4):915-924.
22. Tsubo M, Walker S, Mukhala E. Comparisons of radiation use efficiency of mono-/inter-cropping systems with different row orientations. *Field Crops Research*. 2001;71(1):17-29.
23. Vandermeer J. The ecology of intercropping. Cambridge: Cambridge University Press; 1989.
24. Wichern F, Mayer J, Joergensen RG, Müller T. Rhizodeposition of C and N in peas and oats after ¹³C/¹⁵N labelling under field conditions. *Soil Biology and Biochemistry*. 2008;40(8):2031-2039.
25. Willey RW. Intercropping—Its importance and research needs. Part I. Competition and yield advantages. *Field Crop Abstracts*. 1979;32(1):1-10.
26. Zhang L, van der Werf W, Bastiaans L, Zhang S, Li B, Spiertz JHJ. Light interception and utilization in relay intercrops of wheat and cotton. *Field Crops Research*. 2008;107(1):29-42.