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Use of Agricultural Machinery in the Cultivation of *Triticum aestivum* and *Hordeum vulgare*: A Review

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Abstract
Wheat and barley are important crops for any country because they provide essential nutrients that are important for human life. Wheat is used in many food industries, most notably in baked goods, cakes, and other products. Barley is mainly used to provide feed for the animal sector because of its importance in providing a large amount of protein for animals. Recent years have seen significant developments in agricultural machinery in general and wheat and *Hordeum vulgare* in particular, due to their important role in the agricultural sector and increasing production. The use of agricultural machinery has led to an increase in the quantity of these crops, as it plays a major role in cultivation, irrigation, fertilization, and harvesting.

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1. Introduction

Wheat (*Triticum aestivum*) is the primary cereal crop in the world and the second most important staple crop after rice (Wang *et al*., 2023) [92]. It is a source of food, oil, and fuel. It accounts for 39% of all cereal production in the world, after maize (*Zea mays*). Barley (*Hordeum vulgare*) ranks fourth in world cereal production and is grown mainly in temperate regions. Growing barley is economically significant because of its global importance for malting, brewing, and feed (T. Shamsabadi *et al*., 2009) [87]. The importance of wheat and barley production lies in their role in providing food security and agricultural economies worldwide. In the context of increased population and changing climate, the quest for sustainable agricultural establishments to produce food is pointed out as unequivocal. The loss of soil productivity and mineral nutrient status is a serious agricultural challenge in many developed and developing regions. The alterations in soil and crop management, including monocropping, the annual application of publishing, utilization of mechanical tillage, etc., are among the driving forces of this problem. Even though a significant increase in mineral fertilization was observed in the research areas, the soil test levels for phosphorus (P), potassium (K), and magnesium (Mg) were low to natural in one while medium in the others. Therefore, improved comprehension of underlying mechanisms and processes influencing soil mineral nutrient status and crop production, parallel with the understanding of the ascertained facts of the past, is of key importance to design future sustainable agricultural systems. Wheat and *Hordeum vulgare* are grown in Denmark on more than 600,000 hectares each year. In determined years, there are more areas converting from barley to wheat or vice versa. This article reviews the state-of-the-art of agricultural machinery used for the cultivation of wheat and *Hordeum vulgare*. Background and importance of the crops worldwide and in Denmark are outlined, followed by a description of the machinery used in sowing, crop care, and harvesting stages of wheat and barley growing. The future of agricultural machinery is highlighted. (Food and Country2022) (Norkus *et al*.2025) [68].

2. Historical Overview of Agricultural Machinery

Agricultural machinery has a long history as the result of human innovation. Man-made tools have a long history. Since the Neolithic Age, when people began to cultivate crops, simple sticks, stone axes, wooden ploughs, and sickles have been used to carry out cultivation, planting, and harvesting.

As agriculture became more advanced, the farming system changed from scratch farming to semi-advancement, then formal farming. In this development process, new agricultural machinery has been continually invented, modified, and improved. The late era of the steam engine, the emergence of the gasoline engine, electrification, and technological advancements had an enormous impact. Prior to the establishment of Agricultural Machinery Research Institutions, government-funded institutions used early tractors and seeders before 1950. Aircraft, trains, trucks, tractors, and other engines brought enormous changes to agriculture. After 1950, new developments in equipment and developments requiring substantial financial involvement changed the overall agricultural machinery scene. Further emergence of tractors and sprayers are described. The introduction, adaptation, and modification of new machinery also occurred. In the Western Hemisphere, the tractor appeared much earlier, and it was on this basis that other machinery developed in that hemisphere. On the other hand, in the Eastern Hemisphere, tembong-drivers were initially replaced by self-propelled combine harvesters, which greatly influenced machinery development. Farm mechanization is difficult to implement in agriculture in developing countries due to economic constraints in contrast to mechanized agriculture in more developed countries. Existing agricultural machinery in use frequently involves modification to fit it to the working culture. Farmers may undertake further assessments to suggest their own improvements to machinery or propose better solutions. It was observed that up to four-fifths of all modifications made were successful. The technological change in machines is mainly in the development of larger machines, with larger hoppers and greater working strength at a higher capacity, in order to conduct operations more rapidly in the limited time available for the work to be done. All these machines aim to improve the economic return on labour or to save time. In particular, emphasis has been laid on elucidating the pertinent operability and technological characteristics of equipment that should be considered in preference to performance characteristics during machine selection. (Liao *et al*., 2022) [49] (Daum, 2023) [19] (Rahman *et al*.2021) [73] (Mohammed *et al*.2023) [62]

3. Types of Agricultural Machinery

Various agricultural machinery, including implements, tractors, and combines, are used in the cultivation and harvesting of wheat and *Hordeum vulgare*. The implements are subclassified into implement shapes, such as blades, discs, shovels, and ploughshares. A semi-tandem mould board plough consisting of two turns or lift-type energy zones spins has been designed (Wang *et al*., 2023) [92]. The design taxonomy not only describes over 170 new machines but also has five design themes. Traction category handling units may be tractors, vehicles, self-propelled or towed, simple or doubles, with front, back, or side coupling, and with adjustable wheels. The lifts category connects the handling unit to the implement, transmitting the power carrier energy and movement. Various lifts are employed: hydraulic arms and automatic displacement parallel lifts, rigid bars, or chains and worm screws. This group handles the maintenance, transport, positioning, and height adjustment of the implement before and after seeding. The group of implements mainly comprises paired planes for soil cutting. A pair of rotating knives 'culti-tiller' machine with horizontal, vertical, or inclined axes of rotation is manufactured for tillage and crop residue elimination. Seed delivery machinery, which may be units or tubes injecting seeds into the soil opening, is either free or crossed path paralleling or converging. Various types are driven by the lifting units, wheel-pushed hoppers, spirals, rotating wheels, diaphragm, and blowers driven by suction. (Nassir *et al*.2021) [65] (Ghahremaninejad *et al*., 2021) [30]. Other machinery is tractor- or wagon-pulled implementing vehicles with vertical moving beds composed of a row of shovels for soil development. Barley straw, on the other hand, is widely utilized as animal feed. The straw is shredded using choppers which reduce its length, allowing it to be easily handled, fed, and mixed with other feed. Chopped straw must be mixed with other feed inside mix vehicles before being fed to animals. When using conventional feeding systems with long straw, feeding hay to animals is accomplished without first shredding with these devices. (Keno *et al*.2021) [45].

3.1. Tractors

In agricultural machinery, tractors play an important role. Tractors are stationary vehicles of high-power output that are primarily used to operate different implements. Characteristics needed in tractors are high traction in loose soils, adaptability, ease of manoeuvrability in the field, comfortable working space, and affordable cost (Sahay *et al*., 2017) [79]. The tractor can carry out several operations through a proper tool or implement attached to it. Tractors are classified according to the mobility type as wheeled tractors, crawler tractors, and multi-axled tractors. The wheeled tractors can be divided on the basis of driven wheel configuration into 2 wheel drive (2WD) and 4 wheel drive (4WD) tractors, as far as their height is concerned; they can be classified into low profile vehicles. A tractor uses diesel as the main fuel source. Tractors can range from 16 hp to 400 hp. (Neruda *et al*., 2023) [66] (Litvinova *et al*.2021) [50]
Crawlers withstand an adverse condition of soil by allowing power transmission without tailored tires. They are self-propelled vehicles fitted with steel or rubber tracks and a smooth or serrated surface. They can be supplemented for ploughing operations and haulage services. Crawler axles drive wheels, arranged in an infinite circle in parallel, and are located outside the tractor body and chassis. Multi-axled tractors are suitable for higher capacities of large combines and high tonnage trailers. They have four axles with a load-carrying capacity of 25-40 tons. The fourth axle is detachable and is brought into action with a trailer load of more than 16 tons. (COLLABORATIVE).

3.2. Seeders and Planters

In spite of improved requirements of seed drills and of the harrowing the sowing, crop distribution and the depth of harvest is not the same. Due to the high number of parameters, which are not solitary working mostly it is not easy with the verification of the machines working out of sowing quality, their field quality, to formulate improvement possibilities (Hódiné Szél *et al*., 2013) [37]. The combined and retort type combines the machines sow at low requirements from subsoiling up to reaping. The easiest treatment usually is removed and made burrs on the field, which influence sowing depth and distribution, and the different straining of wheel or roller tractors working admittedly mostly on same cultivation but different mansion. The same spans even those fields, when tractors sow same hybrids at same speed pieces.

The Krone type tilling sown after precision sowing endure very well in spite of the tower collier disposal as sowing on damaging forks Fiji is large. The considerations of Para type monitors on the sowing machines used the field length are gotten better. While these machines noticeably increase field riveting, in spite of fewer tools, working is not so efficient in comparison with light machines. This event may happen, as the without soil maintenance field parts are became dirtied by clogging sands, and this significantly antagonizes sowing according to the wishes. The aim of this work is the comparative hardware–diagrams of straining segregation of the two-ventilators and of belt sewing row machines with Turbo-brush or conventional clearance, and the comparative analyses of the vanity and yield of Euro-sowing universal sowing devices in sowing break-behind corn. (Dhanush *et al*., 2023) [20] (Chen *et al*.2022) [17] (Lv *et al*., 2023)

Green revolution cerealia as rice, wheat, barley and maize production brought important historically changes in agriculture and economy of many nations. These grains are global staples and their local yields are highly dependant on varieties, crop management practices, agricultural supports and mechanization level and type. Crop legumes, along with oilseeds play an important role in diversified cropping systems (Manpreet-Singh *et al*., 2024) [53]. In the framed farming systems tractor tillage in low land and power tiller ploughing in uplands, cereals grown as single crop wheat, paddy-barley or maize-mustard-cowpea intercrop, cropping area total count is low in numbers. Tractors owned farms relied on local hired machines to grow commercial crops like vegetables and peanut and are less mechanized than in other farming systems. These countries are still far from being mechanized but different types of uses and less reliable machines are widely practiced. Increasing human population and with it the demand for food staples coupled with shortage of land, water and other production inputs have posed great challenge ahead agriculture. Superior weed control, crop establishment, fertilizer application, minimal tillage and residues soil moisture conservation were key objectives during machine design efforts. To overcome the short comings of existing machine there is a need to change conceptual design, type and power source, entire power systems as a very important input for productivity, quality, eco-friendliness and profitability of all agri-horti-farming systems. (Mittal 2022) [60] (Erenstein *et al*.2022) [21] (Neupane *et al*.2022) [67].

3.3. Harvesters

Harvesters are important equipment for harvesting major crops like wheat, coarse cereals, pulses, oilseeds, and other fibers. The technology of combined harvesting is popular for harvesting paddy. The harvesting of wheat has traditionally been done with the help of sickles or traditional hand tools. To reduce labor requirement and time consumed to harvest the erstwhile cumbersome task of harvesting with sickle, wheat crop was introduced in cultivation with a mechanical harvester in West Bengal during 1916. The harvesting of wheat with harvester is now popular in many wheat growing states. Various makes of harvester including imported and indigenously manufactured ones are available in the market. The Test Code for Harvesters was formulated and the first machine to be tested fully on the laboratorial scale for its compliance to Test Code and to work with desired level of performance and efficiency under Indian conditions was the 1000/1002 model Harvester Cum Thresher. The combiners developed in India either separately or in association with MoA, were tested parametrically including consideration of human engineering. (Hurt, 2024) [40] (Mezentsev, 2023) [58] (Garnett, 2021) [28].

The evolution of the more complex three-in-one type harvester cum thresher was also undertaken by various institutions. The earliest harvester cum thresher included commercial / laboratory grade machines. Most of these machines were fabricated at the apparatus workshop of the institutions. New innovation in threshing aspect of the harvester cum thresher design was not feasible. Yet continuous improvement in design with technological upgradation and with techno-scientific knowledge, new commercially successful models were developed. The major problem started with regards to its optimal operational performance during harvest of Rabi crop of wheat and barley. Harvesters were available in the market and those developed by different institutes were not getting good performance. 20-25% difference of batch to batch performance was evidenced. The commercial produce of these machines also exhibited varying operational capabilities. Therefore there was a renewed interest to weigh their performance at National level. (Taşkıner & Bilgen, 2021) [89] (Fathollahi-Fard *et al*.2023) [22] (Zhou *et al*., 2022) [100].

3.4. Tillage Equipment

The most common tillage equipment includes various tillage components such as disc harrows (or ploughs), flail (or roller) harrows, vibro-tillers (or tillers), mulchers, and others. Other types of pre-sowing equipment are simultaneously used for packing, loosening, and earthing-up the soil. In wheat barley crop cultivation, the harrowing usually follows sowing. The choice of tillage equipment depends mainly on the type of machinery available and the specific field conditions. Studies on the effect of the type of tillage equipment on wheat yield give contradictory results. Ploughing with a rake-type harrow; disc harrowing with a rake-type harrow following an inter-hoe equipment gave the highest wheat yield, 4600 kg/ha (T. Shamsabadi *et al*., 2009) [87]. (Jensen *et al*., 2025) [42] (Sarkar *et al*.2021) [80]

Other researchers found that specifically designed two row disc harrowing implementing a wide set of discs performed poorly by not effectively preparing the seedbed or controlling weeds. In any case, a viewpoint is that the plough remains the most effective tillage equipment which however brings to higher energy costs. Regarding tillage technology, on average one can expect a winter barley yield increase of about 0,15 t/ha comparing a one-pass seedbed preparation with a minimum tillage measurement and a prior ploughing and harrowing system under comparable systemic (value) treatment. The benefit is higher on moist and fertile soil. Direct sowing into the stubbles can yield 0,03 to 0,05 t/ha lower but remains an acceptable option. Less significant co-effects of choice of type of technology occurred on grain yield as the study could not primarily focus on this aspect and generally on rye all treatments were on average comparable yielding actual levels. However, mixing tillage points within the tillage range of once of twice a ploughing did not provide a considerable beneficial effect which was discharged also under barley given side treatment design randomness conditions and growth season environmental factors. (Xu *et al*., 2021) (Kostrzewska & Jastrzębska, 2024) [46] (Naeem *et al*.2021) [64].

3.5. Irrigation Systems

In productive agriculture, whether horticulture, fruit, or field crops, irrigation is becoming commonplace. It is estimated that nearly 40% of the world's food is produced by irrigated agriculture, which covers about 250 million hectares. In Italy, irrigation is common for fruit and vegetable production, which accounts for most of the nation's production. The ability of crop plants to develop in conditions of water deficit is a crucial characteristic that ensures production stability and optimal quality levels. The main objective of irrigation scheduling is to supply enough water to account for the non-recoverable water fractions of the soil-plant-atmosphere continuum at low energy costs and minimal nutrient drift. Crop cycles must be limited to the amount of water exploited from the soil reservoir. The future of agriculture lies in the use of advanced technologies and automation in decision support on irrigation scheduling and control, capable of ensuring crop growth and uniform quality. (Atamurodov *et al*.2022) [8] (Attri *et al*.2022) [9].

Irrigation scheduling determines the amount of water to be applied to a crop and the timing for application. It is crucial in intensive agriculture. A deficit of water supply is called under-irrigation and generally results in reduced crop yield and quality. Because of lower leaf transpiration, plants show reduced vegetative and fruit development, a decrease in size and quality of larger fruits, and early harvest of smaller fruits. Crop plants conserve water with extreme stomatal closure and alter the water path length, with a resulting lower WUE. Functional stomatal closure exaggerates situations at leaf wilting point, where leaves become very stiff, blemished, and overclimactic. A major consequence of reduced leaf transpiration is leaf scorching, which may be seen as brown and dropped leaves during dry weather. It is important to assess the leaf water potential at which damage occurs on a crop or fruit basis to avoid irreversible stress (J. Greenwood *et al*., 1970) [41]. (Asmamaw *et al*.2021) [7].

General under-irrigation increases the nutrient requirements of the crop. More frequent irrigation with lower amounts of water is required to provisionate nutrient uptake. Consequently, fertilization should also be more frequent, with higher feasibility of drip and sprinkler irrigation systems. Because of reduced vegetative and fruit growth, crops become more susceptible to antagonists and disease with impaired fruit quality, as an increase of blossom end rot in tomatoes. Soil surface cracking is enhanced because of poor soil moisture, implicating extreme irrigation costs. Very deleterious effects occur directly from rising winds, unrelated to drought periods in tree and grape crops, generally during the veraison stage, leading to salinization. In the last two decades, most of the damage to crops, primarily in southern Italy, was given by prolonged soil dryness because of crop irrigation stops or heavy date palm and vine over-processing (Pardossi *et al*., 2009) [70].

4. Mechanization in Wheat Cultivation

Tractors, as the primary power source for agricultural machinery, have undergone significant changes to adapt to the intensification of tillage operations in wheat production. In 1958, China's first tractor was launched, initially with a small horsepower and a four-wheel drive capacity of less than 18 kW. With the rapid development of agriculture, domestic tractor technology has made great strides. Advancements in technology have incorporated automation into orchard plowing, and hydraulic rotation has been developed so that the working row and working depth can be adjusted in full trailers. Research on plowing tractors has been conducted overseas in various countries. In the 1940s, the United States used a crawler tractor to plow sandy soil. Due to the advancement of engine technology, the large plow tractor made rapid development, and in 1954, the 300-horsepower giant tractor was manufactured (Wang *et al*., 2023) [92]. At present, many German and American manufacturers have produced crawler tractors with a power of over 500 horsepower. (Jensen *et al*., 2025) [42].

China's wheat production is mostly concentrated in the Huang-Huai-Hai Plain. These areas are characterized by flat terrain, black soil, and a wide breadth of farmland suitable for large agricultural machinery. In general, tractors are used in mechanized wheat production in flat areas, while tillers are often used for wheat production in hilly areas. In recent years, with the continuous rise of labor costs and market demand, this kind of tillage machinery with low efficiency and serious soil compaction is gradually losing competitiveness. The design and manufacture of tractable tillage machinery for dry direct seeding of wheat and corn have been the focus of much attention. Focusing on the comprehensive utilization of straw of wheat and corn, the research and development of a chopper-strip tillage machine, which can finely chop straw and simultaneously inclinate strip tillage has been carried out. In particular, the depth and width of slicing can be adjusted according to the amount of straw, soil moisture, and location of straw. (Zhao *et al*.2025) [99] (Hu *et al*.2021).

4.1. Soil Preparation

Soil preparation for wheat and *Hordeum vulgare* plays a crucial role in crop establishment and crop yield. Soil preparation involves the mechanical treatment of soil including disk harrows, plows, and reverting. Dust like fine clods and aggregates impede planting operations by preventing consistent depth of placement, improper seed distribution, and inadequate seed soil contact. Soil preparation has an important involvements on the moisture content. In arid or semi-arid regions, summer irrigation is normally used for burr-cultivation moisture preservation but rain is required just for sowing on light soils as sowing should optimally be completed within a week. Soil fertility is determined by nutrient availability in the soil, availability on the soil exchange complex, and organic matter. Fertility should be managed in conjunction with rotation so that losses in one crop can be replenished in another crop (T. Shamsabadi *et al*., 2009) [87].

Many different soil types, with varying degrees of activity, have been investigated in a multitude of tillage systems ranging from zero tillage to continual intensive tillage. A comparative study of tillage systems for winter wheat grown in a heavy soil unable to be seeded in a timely manner due to sticky black conditions could elucidate some of the reasons for the higher black soil yields relative to lighter soils. Dry land cultivation is performed in only light soils in south Saskatchewan where moisture preservation is not as essential, though heavy soils require never-dry systems. Continuous intensive tillage permits seeding and generally improves crushability of the soil and hence soil tillage. Heavy clay greenhouse soils displayed slow infiltration rates with direct drilling and post-tillering tillage of at least some tilled soil is essential to improve assimilate and allow food materials from harvested straw to be worked into the soil. A related study of a comparatively sandy river bottom soil

without comparative treatments during a wet spring may show due to better friability why wheat yields are less affected and why greater soil preparation usually increases oat yields. (Ali *et al*., 2025) (Bussell *et al*., 2021) [13].

4.2. Sowing Techniques

Cultivation of the plant begins at the moment when the first seeds are placed in the soil or the root collar of a plant in a pot of a certain growing medium. It is a key element of agricultural technology, since this operation is of crucial importance for the future development of plants. Sowing seeds evenly, at about the same distance, at the right time provides even germination and uniform crop which finally results in a better quality and higher yields. On the one hand, drought in spring and other severe weather conditions may interfere with uniformity of the plants development (e.g. for small seeds), on the other hand, the time and quality of sowing may be the reason for unevenity (Hódiné Szél *et al*., 2013) [37]. Sowing machines are built by two main systems, regarding the grabbing and forwarding the seeds, therefore they can be pneumatic or mechanical. The pneumatic sowing machines can be equipped with rotating disc distributors or pressure machines. Mechanical machines may be mounted or towed, usually they can work during a longer time and they are much quieter than pneumatic machines, but they are more sensitive to speed variances. The advantages of mechanical machines are the accurate sowing (98-99%), the quick plant distance adjustment, the low weight of the machine and the relatively low price of the machine. Their disadvantage is the low advancing speed therefore they have lower area-performance than the pneumatic sowing machines. The pneumatic gardinex machines are more favourite because of their higher performance, quasi maintenance-free usage and lower soil profile disturbance. However, their characteristics are more difficult to determine and they are often too cumbersome (T. Shamsabadi *et al*., 2009) [87]. For a few years, attempts have been made to develop a middle category pneumatic sowing machine which would match the accuracy and simplicity of the mechanical machines and the reasonable price and good performance of the pneumatic machines. (Xiong *et al*., 2021) [95] (Akhalaya *et al*.2023) [3].

4.3. Fertilization and Pest Control

Crop production largely occurs in open fields; processes such as soil conditioning, sowing, fertilization, pest control, and harvesting depend on nature. Crop quantity and quality are controlled by climatic, biological, and technological factors; climatic conditions are extremely difficult to manage. The only means of controlling crop quantity and quality are biological factors and technological factors. By controlling fertilization, pest control, and soil treatment processes, crop characteristics can be altered. (Alborov *et al*.2022) [4] (Richard *et al*., 2022) [77].

A variety of different agricultural machines or machine aggregates is needed to execute all the actions necessary to cultivate crops. The need for many machines is uneconomic since certain processes can be combined or executed in parallel. For instance, fertilization and pest control can be executed by machines simultaneously with soil treatment or sowing. Machines already exist that can execute many processes, such as machines that do two or more processes at once. Except in a few cases, such machines combine processes of the same kind, such as sowing and fertilization or soil treatment and fumigating. This mechanization, however, only combines two similar processes. Machines conducting combined fertilization and pest control of wheat and *Hordeum vulgare* driven by wheeled tractors with a motion speed range of 6.4–8.3 m/sec were theoretically calculated and experimentally tested (Bulgakov *et al*., 2017) [12]. With the use of expanded clay mixed with a pesticide, the efficiency of these machines was checked. Tests revealed it was possible to obtain high-quality combined fertilization and pest control with these machines and that such machines could be successfully manufactured. With the creation of combined fertilization and pest control machines, the efficiency of mobile machines would be improved, thereby justifying farmers' investments in their acquisition. (Singh and Kumar 2023) [85] (Chaudhary *et al*.2022) [16].

4.4. Harvesting Processes

The harvesting of wheat and *Hordeum vulgare* is a crucial phase primarily because it is the final step in the production of a food grain for human and animal consumption and because the wetness, density and other most attributes of the crop are changed considerably in this process. In the harvesting of both these crops, machinery is used that is typically comprised of a combine harvester. However, a common manual harvesting device, the sickle, is also widely used although it demands much more time than the machinery does. For this reason, it is important to assess how such changes affect the crop texture. The wheat and *Hordeum vulgare* are harvested in several ways in various areas, predominantly with the use of a combine harvester. A major finding of this study was that both crops required several approaches of the combine harvester to be harvested. (Ghahremaninejad *et al*., 2021) [30] (Geng *et al*., 2022) [29]

The wheat and *Hordeum vulgare* are harvested using machinery or are typically harvested manually with sickles. The harvesting of wheat and *Hordeum vulgare* was performed using both a combine harvester and sickle machinery, and there was a marked difference in crop condition from excessive time of contact with machinery and shortly afterwards. Compared to previous observations of a combine harvester utilized for another project, all conditions of both crops how remain the same including the weather conditions. For both crops, the use of machinery in harvesting was preferred because it was efficient in time and other resources with the exception of the harvesting of fodder wheat to be used for other purposes. This was determined from discussions with several local farmers. The combining of crops can take a lot of time with a significant amount of trash present, however with shorter passes on a combine harvester, time is saved with a high-quality harvest produced. (Zhou *et al*., 2022) [100] (Fernando & Lăzăroiu, 2023) [23].

In contrast, when harvesting with sickles less trash is produced, but this harvest operation is time consuming as stated. The machinery should avoid using it at wrench nine and as harvester. Tractor weight is also critically important for these crops. It was found that more weight would result in deeper furrows resulting in more soil being lifted and large clumps of soil being distributed too widely. This is an injured condition that could result in considerable losses and leaf damage especially for wheat. From the responses, it was evident that some farmers hoped for less weight of tractors and multiple axle designs to provide a better balance for operations. Although impressive advances have been made the unbalance of operating machinery is still not corrected as much as possible. (Mohieddinne *et al*.2023) [63] (Mishall *et al*.2023) [59].

5. Mechanization in Barley Cultivation

Barley occupies the fourth position in respect of area and production all over the world after wheat, maize and rice (Mlengera *et al*., 2015) [61]. Barley is also considered as a poor man's crop as far as input application is concerned. Consequently, it is still being cultivated traditionally in many parts of the world. There is an urgent need to mechanize the cultivation of barley. Barley can be grown on marginal lands and under rain-fed and semi-arid conditions (Bulgakov *et al*., 2017) [12]. The 65% of the global area is being cultivated in 25 developing countries, mostly situated in arid and semi-arid conditions. Indian farmers are forced to grow barley during the rabi season, when they have no other option than to grow this crop due to terminal drought. The acceptance of barley is also hampered due to unavailability of various inputs and machinery. Although barley is being grown under very harsh conditions, it is still harvested manually. It is during this time that pests and diseases play havoc, which in the absence of easy to use pesticides are very difficult. more time family as well as the hired labor is engaged for harvesting, cutting, carting and threshing. To overcome the above mentioned, undesirable conditions mechanization of post-harvest operations, like generic harvesting, cutting, carting and threshing would go a long way in improving the grain quality and lowering the drudgery at harvest time. Though several machines are available for mechanization of these operations for other crops, farmers are hesitant to use them for barley, as they work good, with regard to the crop type and operational conditions related to the environment and to the machine itself. There is a need to standardize and adapt the available machinery, and test the developed ones on different types of post-harvest needs and give training to the farmers on their operation and maintenance. Barley is the fourth important cereal crop in the world after wheat, rice and corn. The present work reviews different manufacture's equipment and machinery that have been developed to model different barley growth conditions and farm problems. (Mittal 2022) [60] (Geng *et al*., 2022) [29] (Fischbeck, 2024) [24].

5.1. Soil Preparation

Wheat and barley plants require to be harvested under dry condition a snack of 13-14% for wheat and 12-13% for barley after dyeing (T. Shamsabadi *et al*., 2009) [87]. Generally combines fitted with pickup reel, auger conveyor and cylindrical sickle are used for harvesting of dastnoosh crops (wheat & Barley) in the areas of Navapur, Bhusawal, and Ghatnandur. The machine usually operates at one to one and a half km/hr, clearing about 40-50 acres of land in a day (four to five hours). After cutting, the crop is thrown in the aghis for drying. Moible wheat and barley thrashers are also used to separate the grain from the straw and pollin after which the grain is cleaned. The experiment was conducted on an experimental area of 1.50 ha during rabi season 2000-2001 at the Research Farm of the National Research Centre on Wheat, Khadakwasla, Pune, Maharashtra, India. The crop was sown with realistic application of water, crop management practices, seed allotment and watering etc. All possible efforts were made to contain the plot weed free. The wheat creep was harvested by manually operated sickle and conveyed in the lab in sack for further analysis. The majority of harvesters were brought to the laboratory for quantification of their different parameters. After visual observations, parameters to be measured were determined and about 2-3 in each category were selected for quantification. The government policy support for creation and establishment of cooperative societies for machinery bank at district or taluka level also emerged out as indispensable to cater the need of small scale farmers who could not procure agricultural machinery. Similarly, the availability of agricultural machinery on rent would further foster rapid mechanization in western Maharashtra. (Marois, 2024) [54] (Challoumis & Eriotis, 2024) [15]

5.2. Sowing Techniques

Introduction of conservation tillage and related cultivation and sowing systems significant affects on crop production, regional hydrology, soil physic-chemical properties, soil organisms, etc. Only few researches related to examination of sowing systems' machineries has been done in Hungary (Hódiné Szél *et al*., 2013) [37]. But not enough investigation was done on crop residue retention and sowing due no-till. While ripper-no till sowing system has been used over a decade in national level, only few examinations were done on sowing system itself. John Deere 1780 and 1850 no till machines are frequently used in Hungary. Though similar features and working principles exist but various constructional solutions are provided for disc coulters system and seed box design and works of the machines. There are empirical experiences among using those sowing systems; therefore, examining works of seeding machines in selected sites and special interest way are justified. (Lv *et al*., 2023) (Achankeng & Cornelis, 2023) [1].

Sowing is an important and complex phase of crop production, its technology is increasingly applied along trailed, drawn and mounted sowing systems used with big and high-powered transport vehicles. Sowing machines are required to take on increasing amount of work, producing only high quality seed bed and depth procedures. And the representative machines as one example of the potpourri of sowing systems should be introduced. The aim of the work is to introduce working quality measurements of sowing systems. (Lesk *et al*.2022) [47] (Raza *et al*.2023) [74].

Poly- and dual-poly propylene mixtures (containing various amounts of synthetic resin) are possible alternatives to common frame materials. Deleting the section length unit itself, clamping the parallel frames 100 mm, 200 mm and 300 mm stably. The built system consists of an 88 m heat recovery model, a counter flow heat exchanger, fan motors and their controllers, IR sensors for inlet and outlet air temperature, controllers and high frequency database logger. Results are analysed by multivariate regression. While they generally plotted satisfactory correlation, stepwise regression eliminated less reliable measures. Regression procedures partly ensured the asthmatic stability of 83-92% of relative error prediction, whereas precision of between 3.8-5.6°K proved to be reasonable otherwise accuracy could come below 0.2% even at less cases. (Tu *et al*.2025) (Hampsher-Monk *et al*.2024) [35].

The operated variable decompositions, as their principal applications, are simple algorithms and measurements even for non-specialists. Their potential as universal and beneficial techniques for severely affected/specialist applications, affected data, and field-effect combination is shown within framework conditions. However, the proposed measures remain partially valid, disadvantaged less maturity of computer codes and E-SD formalism, rigs and measurements. After 4 years experiences would be worth of trying the

system at the targets of larger scales or dealing with weaker palimpsests. (Rowan & Kalacska, 2021) [78] (Wei *et al*., 2024) [93].

5.3. Fertilization and Pest Control

The fertilizer production and application are seen as highly important participants of agro–technical and highly technology operations. The rapid increase of the fertilizer input valid for all countries throughout the last decades as well as for all cultures afterwards requests a careful analysis of nutrients sanitation of the soil particle layer and their fertilizers input first of all. The soil is only the primary source of nutrient elements maintain a steady agricultural production NV (N followed by N, M, Ca, K, Cl, S), dielectric substances (matter, gases, vapors) and others. The nitrogen is paper phosphor and microorganisms (bacterium) residing at the earth. In the form of ammonium nitrate and calcium phosphate diag, it may be obligatory in mineral water softness flux for the remaining elements Ca, Mg, K, S, Na. A method for calculating fertilizer nitrogen and capacity phosphorus for various perennial herbaceous pasture management systems on the Purves' dour class is developed. The nutrient application dose to dry farm field crops in the settlement-prone regions in NE and N Turkistan is calculated on the base of the wind–erosion hazard. Fertilizers are widely used as raw materials for NPK fertilizers. The amounts of the fertilizers to be consumed should be estimated on the basis of the soil and crops due to local conditions. The impact of chemical fertilizers on crop yield, soil fertility and higher crop quality in the Irrigated Slope–land of the Rhatan Province is discussed. The various industrial wastes can be recycled into organic acids for use in agriculture (Adriana & Desimir, 2017) [2]. (Kareeva *et al*.2022) [44] (Hesan, 2023) [36] (Gudinskaitė & Paleckienė, 2025) [34].

Pest control in the wheat production has a great importance economically. The negative impact of weeds improves when the weather conditions are favourable for their growth and when crop plants are not protected on time. Losing of wheat production quantity and quality occurred when the pest problem was not managed as in the previous year. In order to provide the highest income per unit area the period of application and the amount of used pesticides is very important. The increased use of pesticides was in the cultivation of wheat with uncovered soil, as well as the production of spring wheat compared to winter wheat. One kilogram of applied herbicides increased the wheat production for 60 to 224 kg. The application of pesticides in the wheat pest control implementation can prevent losses caused by pests in agricultural production. Alterations of use of herbicides on heavy clay soil in wheat production did not happen during six years. Changes of use of herbicides in the last decades, though rarely, are evident in the application of pesticides close to the recommended rates. A positive and significant effect of 152 rounded up pesticides application on the wheat grain yield was recorded in a longer period on the basis of possible solutions. An average less Minchem and Fernandez broth mixtures unit was determined for 139 kg of wheat grain prod, before invasion with virus diseases. The sustainability of wheat production, all higher common wheat grain yield compared to the CORD range herbicides with a single active ingredient determined before the application of advice and on the base of recommendations to farmers, therefore, education is required. (Mekonnen, 2022) [56] (Singh, 2022) [84].

5.4. Harvesting Processes

Field crop harvesting machine has been a point of focus for different reasons in various countries. The bigger harvesters in terms of width of cut have not made the same impact on the smaller combine harvesters because the smaller machines offer levels of farmers' ownerships and control of the work at low costs that the bigger machines are unable to offer. Field sizes past about 300 ha are a minimum for bigger harvesters while there are wide regional variations in machines' adaptability to crops and growing practices. While there have been innovations in small to medium combines, unfortunately, little innovative design and development efforts have targeted devices that could be used to derive more from each harvester's cutting and separating capacities. True losses of two types not presently addressed at the best harvesting rates possible by the currently available crop headers for wheat, barley, and pulses have been observed. A device aimed at benefiting harvester owners across sizes of harvesters and manufacturers of all sizes and types of harvesters through further machine capturing was presented. It was shown how the study of wheat and barley expect to expand the coverage of the information and experimental work presented to further crops and crops grown under different conditions. In many farming systems, including edible seed oils, pulses, soybeans, rices, and services to smallholder farmers, significant harvest losses have been measured or reported. There are also huge comparisons to be made across the performance of harvesting equipment in different countries and climatic conditions, but these too have been the subject of less attention than expected. This warrants a rather fresh focus on and broadened perspectives on harvest losses. (Peng *et al*., 2023) [71] (Xue *et al*.2021) [97] (Zhou *et al*., 2022) [100]

Harvested plants falling onto the ground suddenly and being missgrained/straw or forced through other outotakes can cause harvest losses. Two types of harvest losses can be discriminated throughput and fall losses wherein point losses can fall into several classes. More broadly about harvest losses and their measurement, there are crop-related factors like characteristics of the stems or ears, the crop's growth stage and arrangement at harvesting, environmental conditions, and the time of day, as well as machine-related factors like combines' leverage and size, their operating state, and their driving speed. Additionally, complex interactions exist, e.g. how harvesting procedures interact with environmental which in turn interact with the crops relevant for harvesting. For the project in question, harvesting practices were caught up on or reassessed with no critical understanding of the power point of the design or how it may translate. Sensitivity to point design criteria has tended to be rather eroded. The next autonomous class of devices with behavior similar to foraminifera and harvesters is larger than the design scale. Mobile sensors such as active indices or passive tracking of plant features fields can now be built at larger sizes and powers available. Desires to uncover finer structures such as grain material treatments, handling devices, including rescinders, and scythes spread across bigger spaces have gone unanswered. In-machine blending sampling devices moving at relative speeds to the crop mass minimize point design issues. (Wang *et al*.2021) [91] (Hou *et al*.2021) [38] (Qu *et al*., 2021).

6. Impact of Machinery on Crop Yield

There is significant investment in agriculture to raise productivity due to intensification pressures associated with food security and environmental degradation. Higher productivity over time, although heterogeneous, is partly facilitated by investments in Agricultural Machinery (AM). Agriculture productivity statistics show a 2.9% compound annual growth in aggregate labour productivity in the world from 1990-2020 with a correlated 3.50% growth in AM capital. In developing countries, this GDP/AM ratio is 66,675USD/1000USD in 2020 vs 520,643/1000 in OECD and a correlated Agriculture Work Force (AW) of 65.52% vs 3.85%. Local Context matters, as smallholder mechanization is fissured whilst large scale mechanization is plateaued in regions & commodities similar to China. Agricultural Machinery (AM) usage can be diverse, piecemeal approach in contradictive coordination with scale beyond seeking lowest labour cost can exacerbate technical inefficiency in developing countries. To develop a coherent analysis of agricultural mechanization and productivity globally, it is needed to go beyond national and monocritical lens most literature choose and consider Local Context in the diversity of AM statistics and growth between AM provider and user, & AM employment, functionality and coordination types. AM choice is characteristic of Local Context, differentiated development trajectories are conditioned by complex interaction between institutional quality, soil characteristics, farmland distribution and mechanization policies. To effectively utilize Tracracker simultaneously for small-scaled Polymechanization and large-scaled recombination in the same region, tailored mechanization policies including shifting usage duration of removed AM capital, LI-based AM rental network and cooperative governance are required to better serve smallholder flexibility and diversity while ensuring availability of AM services for resultant larger scaled mechanization. (Reddy, 2022) [75] (Meng *et al*., 2024) [57] (Yang & Li, 2022) [98].

Though GHG emissions can be significantly decreased from the introduction of agricultural machinery in agriculture development process, the effects were unobserved in recent machinery-developing countries due to their imbalance growth with mushroomed secondary industry & construction together with obsolete or less compliance machinery. Ceasing machinery growth quantitative by robust machine import customs regulation at border were useful but needed support from institutional arrangement for sustaining mechanization growth while mitigating exogenous impact. The trans-regional machine syndicate is expected to be developed to fulfill the combination of undeveloped vast land with ready-made modern machine in developing countries at the holding of alternative servilization. Prospered machinery development and operation were the best to fulfill the food security within the budget of carbon emission with agreed-long implementation of emission cap and allocated targets. There were no obvious increase in grain productivity but decrease in machine cost from the trans-regional agricultural mechanization in in-field travelling of modern fertilizer spreader, transplanter and car. Redundant investment in large multi-national adoption was supposed to stick the upgrading & spread of coverage/standard. In-holding food importing severity both on grain and striped fish provided for a trio transformation global dissemination channel. (Gołasa *et al*.2021) [32] (Panchasara *et al*., 2021) [69].

6.1. Yield Comparisons

In the highest grain yield and vegetative and generative dry matter were obtained with the “plough + vibratory harrow + seed-drill” treatment at 9500 kg.ha-1, 28500 kg.ha-1, and 15600 kg.ha-1, respectively. This was followed by the “plough + cultivator + seed-drill” treatment with a grain yield of 8250 kg.ha-1. When local agricultural practices were used, grain yield and the vegetative and generative dry matter were significantly lower than those of the aforementioned treatments, at 7040 kg.ha-1, 20880 kg.ha-1, and 7490 kg.ha-1, respectively. Then the majority of local agricultural practices do not reach the good results; these treatments must be changed in order to increase the efficiency of wheat production. The results suggest that, in non-irrigated conditions, soil tillage and sowing are important factors in wheat production so that mechanical factors have significant effects on the yield and yield components of wheat. Advantages of tillage systems and seed drills used in wheat production depend on environmental conditions of the year. The best treatment must be chosen based on the environmental conditions of the year and adapted to local conditions (T. Shamsabadi *et al*., 2009) [87]. In other studies conducted, the highest yield was obtained in furrow addition to mouldboard plough and chisel plow plus harrowing which was statistically different from other treatments. The lowest yield was in the control treatment with no tillage which was significantly different from the treatments. The next lower yield was of disk plough + harrowing treatment groups which had no significant difference among them. The ratio of grain yield of the treatments showed the advantages of furrow treatment over continuous disk plough of 12% and 5.6% compared to mouldboard plough and shallow tillage treatment (Gilandeh *et al*.2022) [31] (Kabri, 2024) [43].

6.2. Economic Analysis

Economic analysis is an important aspect when deciding the appropriate size and technology of machinery. Machinery having higher cost will have fewer chances of adoption by farmers of small landholding. In agricultural machinery, the model has an important role in building the machinery market. Selection of the design is based on selection of location, kind of material to be processed, type of operation, manufacturing cost, and investment cost and profit. Determination of manufacturing cost is based on fixed cost and economic life of machinery (Tahir Latif *et al*., 2018) [88]. Studies on investment cost of machinery are limited. Harvesting machinery being capital intensive sectors of agriculture requires higher investment. Therefore a large number of small Arhar farmers do not own harvesting machinery and prefer hiring or CHC service. Employment of harvesting machinery during the peak season is one of the burning issues of farmers. Demand for harvesting machinery is especially during harvesting season of kharif crop paddy. The growth in productivity of paddy is more than the growth in area, resulting in an increase in cropping intensity which has forced the farmers of this region to grow long-duration rabi crop wheat or pulses. Only a few studies have been conducted on economics of harvesting machinery used in wheat and paddy. There still exists a vast scope for research under this area. (Shehadeh *et al*.2021) [82] (Belhadi *et al*.2025) [10] (Sonkavde *et al*.2023) [85].

7. Environmental Considerations

A mandatory measure that machinery management should follow to mitigate greenhouse gas emission is to take the

properties of machinery into consideration as well. Bigger-scale machinery is supposed to operate in the smooth field while small-size machinery can mitigate emissions in terraces or irregular plots of farmland (Ma *et al*., 2023). Besides machinery selection, job configuration of machinery should be studied to explore the number and the match of assembled operation resources on a way to explore the condition of the operation region and plot size, which can effectively mitigate greenhouse gas emissions and lower the operating cost. The production of some green production inputs such as fertilizers and pesticides should be improved. Constant monitoring and improvement of the conditions of advancing green production intensity are also necessary. (Grahmann *et al*.2024) [33] (Sengar and Vashist 2021) [81].

7.1. Soil Health

Soil is the foundation of terrestrial ecosystems and the supporting environment for human beings and their activities. Scientific understanding of soil health has advanced rapidly in recent years, and the numerous beneficial effects of soil health have been widely reported in agricultural crop production and ecosystem services. Cultivation practices, including soil tillage, mulching, fertilization and herbicide application management, crop rotation and cover cropping, and integrated soil pest management contribute to soil health (Wang *et al*., 2023) [91]. Soil health is defined in terms of the fundamental characteristics and functions of soil. Soil health is a continuum whose state reflects the inherent and dynamic soil characteristics. Soil composition, physical, chemical, and biological properties are all considered factors of soil health. One of the key focuses of soil health assessment is to develop soil health indicators that aid in understanding soil health status and monitoring changes in soil health over time. (Cárceles *et al*.2022) [14] (Fu *et al*.2021).

Soil management practices directly affect soil structure, particularly in the topsoil depth. The cultivation of tilled soils with younger age generally leads to preferential formation of a granular structure in the topsoil, yielding soils with high aggregate stability and a larger aggregate size distribution. This generally increases porosity, infiltration, and water retention, which leads to improved soil hydrology due to the increased surface area for water retention. Soil structure directly affects soil weight to some extent since the weight of a soil is equal to the sum of the volume of its constituents multiplied by their respective density. However, given that only a small fraction of soil constituents are initially subjected to the force of plough, tillage also directly shapes most structural parameters. A systematic study aiming at disentangling direct and indirect effects is still missing and would provide important additional knowledge on how tillage operates and validates hypotheses on tillage effects. (Mattila & Häkkinen, 2025) [55] (Bienes *et al*.2021) [11].

7.2. Water Usage

Irrigation fits into both new and existing agricultural systems and mechanisms. It is critical inputs in the construction of the system and the constant rehabilitation of existing and constructed systems during the cultivation of food crops. To achieve maximization of agricultural productivity required by food crop farmers who use irrigation, they must have a clear understanding of the relevant factors related to irrigation such as water availability, quality and cost; soil characteristics, cropping intensity, cash flow and capital; irrigation systems/technologies, service availability, productivity gains and costs; market and infrastructure development. Based on a survey of farmers irrigating food crops in the Bas-Mono area, Togo as a case study, it is erosion, crop management practices, machinery usage, weed management practices, tillage practices, location and institution. Fertilization practices, even though essential to achieving productivity premiums, are deemed as farm system issues that might not specifically fall within the scope of a paper on agricultural machinery use and also not specific to the gear that is ultimately the provided focus of the paper. The recommendations and threshold can also be adapted, as required, to conditions other than food crops-irrigated vegetable crops or light interpreted climate with crop management practices become challenging and thus important (J. Greenwood *et al*., 1970) [41]. (Rehman *et al*.2023) [76] (Gao *et al*., 2023) [27].

Agro-ecological zoning can also aid machinery development. It ensured that the productivity of nationally developed machinery designs largely matched that of internationally sourced machinery in Ethiopia. Assessment of farmers' machinery usage, twenty machinery attributes between the categories of suitability, know-how, cost and ancillary services generally enabled explanations of over 99% of variation in machinery usage across the farming systems. Control over these attributes is held by national governments or private actors who are heavily influenced by the national government. Focus on irrigation can also set out critical attributes of irrigation that should be understood if investment is targeted toward maximization of water usage in food crop production. (Reddy, 2022) [75] (Aryal *et al*., 2021) [6].

7.3. Carbon Footprint

The implementation of new methodologies to calculate the carbon footprint of different crops is of utmost importance to coordinate economic development and monitor and mitigate environmental burdens (Stylianou *et al*., 2023) [86]. Carbon footprint can be defined as carbon emissions induced by a process or production in a growing season. The calculation methodology adopted can be understood as follows. CO2 emissions from field burning are estimated based on the harvest index of rice (= 0.48). The production of inorganic nitrogen, which takes place during the application process, is the largest source of fossil energy consumption in agriculture, accounting for 84% of total emissions and leading to indirect emissions corresponding to 83% of total emissions. Livestock methane emissions produced during urea mineralization and indirect emissions of CO2 from NOx and NH3 volatilization, in which nitrogen recovery is only 9% and the remaining loss is 91%, also contribute substantially to gross emissions. These GHG emissions take place not only in the field but also in other regions, creating a spatial mismatch between emissions and potential damage. In China, urea application contributes to gross emissions from cropland by a factor of 1.13 and in the USA, it is 1.15. There are efficient methods for scaling back nitrogen fertilizer use to achieve a net reduction in nitrogen input while maintaining wheat yields. Field-scale analyses and simulation studies will help estimate yield and nitrogen use efficiency in response to alternate nitrogen input. Soil analyses, such as a NO3 test performed before planting, can help prevent excessive nitrogen fertilizer application. Incorporation of nitrogen fertilizer into the soil and side-dress application reduces N losses such as NH3 volatilization and increases nitrogen use

efficiency of the crop. Moreover, nitrogen fertilizer use is decreased as a result of smart agricultural practices based on satellite navigation and auto-guidance systems. (Li *et al*.2022) (Whetton *et al*., 2022) [94].

8. Conclusion

It has long been known that the efficiency of wheeled tractors in the course of operation is reduced. During operation the "ageing" of high quality rubbers for the wheels begins. In addition, the accumulation of various defects, which include mechanical damages of loaded wheels, cracks on truck tires, joints of rubber plates with the wheel rim going out of working condition, lead in the most cases to the need of using them on a limited time. Many defects can't be eliminated on the units themselves. Nevertheless, such wheels can't be removed from use immediately; the efficiency of their work is reduced. For this reason assessing the actual condition of tractive wheel tractors and wheeled working machines is topical problem. During operation, tracked tractors face the problem of wear of the steel wheels belts. The wear of these parts has a negative effect on the traction force which determines not only the productivity of the machine, but also its field performance. The machine's output is influenced by a traction force and speed of work, which change over time. An increase in wheel slip and traction force leads to a decrease in productivity and perform moisture-attraction operations. Reducing the speed of work in turn leads to a decrease in the traction force. Intensive wear leads to an increase in dissatisfaction of the operation process of the tractive resource and numerous complaints received by the manufacturer from the consumers of equipment. Therefore, it is necessary to develop an algorithm that assesses the technical condition of tracks and the effectiveness of their operation. This will not only introduce a new approach to assessing the technical conditions of this category of machines, but also establish scientifically grounded service intervals and suggest a list of possible defects of the examined unit.

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