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RESEARCH ARTICLE

MANAGING PLANT POPULATION AND COMPETITION IN FIELD CROPS

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ABSTRACT

Maintaining the optimum plant population and competition in field crops right from germination to harvesting is one of the important tasks for efficient utilization of resources and to get highest economical yield. To know the about the inter and intra plant competition and its ultimate response on plant density dynamics, review was done on the topic managing plant population and competition on field crops. It was found that the optimum plant population is highly dependent on the various factors like crop inputs, environmental condition and managerial factors and the competition within and between the crop plants. The optimum plant population for any crop in given locality is usually determined by trial and error method. Managing the input level and environmental condition as well as many agronomical approaches can maintain the plant population to a desired level. Proper method of sowing, using good quality seed and right seed rate, optimum sowing depth, sowing seed in good quality soil, plant size and architecture, proper fertilization and irrigation, gap filling and reseeding, over-seeding and thinning, double transplanting and use of tolerance variety can be used to obtain optimum plant population.

KEYWORDS

Plant Population, Competition, Management, Resources, Optimum.

1. Introduction

Plant population is defined as the total number of plants present at unit area of land (Baker, 1964). It indicates the size of the area available for individual plant. Similarly, the number of plants per unit area that would give maximum yield is termed as optimum plant population (Willey & Heath, 1969). Optimum plant population for a crop depends on situation and condition, variety, cultivar, availability of water, nutrients and sunlight; length of growing season; potential plant size; and the plant's capacity to change its form in response to varying environmental conditions (Drew, 2009). Competition is generally understood to refer to the negative effects on plant growth or fitness caused by the presence of neighbors, usually by reducing the availability of resources (Paul & James, 2019). In other word, competition can be defined as a process that occurs when the combined resource demands of plant within a given area exceeds the available supply. Competition mainly occurs in the field for Nutrients, Moisture, Light (Solar radiation) and for space. Competition can be an important factor controlling plant communities, along with resources, disturbance, herbivory, and mutualisms. Competition can be of two types; intraspecific (between the plants of same species) and interspecific (between the plants of different species).

The optimum density or plant population for any given situation results in mature plants that are sufficiently crowded to efficiently use resources such as water, nutrients, and sunlight, yet not so crowded that some plants die or are unproductive. At this population, production from the entire field is optimized, although any individual plant might produce less than would have occurred with unlimited space. It may often be desirable for the agronomist to define the relationships between plant population and crop yield so that in any future situation he/she can predict yield/population curves easily and accurately from the minimum of data (Willey & Heath, 1969).

1.1 Objectives

- To know about the factor affecting plant population in field crops
- To know about the different ways of managing plant population in field crops

2. Methodology

An extensive review was done to collect pertinent data going through several proceedings annual reports, pamphlets, and booklets, thesis works and so on from different National, public & private Organizations of the country. Similarly, the findings are mainly based on the secondary information of the thesis available in the Central Library of Agriculture and Forestry University, Rampur, Chitwan in the respective field and published articles on different International journals.

3. Findings and Discussion

3.1 Optimum Plant population

Optimum plant population more specifically refers to the ideal number of plants that can be comfortably accommodated in a given area without overcrowding or too few to waste space by optimum utilization of the

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available crop inputs like nutrients, moisture, sunlight, carbon-dioxide etc. (FAO, 2005). Plant population is dependent on the various crop husbandries and input complexes this is because there is no precise answer to this question what is the optimum population or spacing for a specific crop (Rana & Rana, 2011). Factors such as climate, soil, cultivar, market requirements, managerial ability of the grower, and many others, all play a role. The optimum planting density for any crop is usually determined by trial and error (Liu, 2017). As a result, recommended sowing rates for different crops are based on evidence accumulated from field trials which have been repeated over a number of seasons to account for annual variations in weather (Sayed & Squire, 2002). The optimum planting density at one site may not apply at other locations because regional variations in weather and soil type mean that further trials are needed at each site to validate general recommendations. This process is time consuming and labor intensive and the results from such population/yield experiments provide little or no increase in our understanding of how crops at different populations capture and use resources to produce a final yield (Azam-Ali & Squire, 2001). The estimation of plant population per hectare (Pp) is given by

$$Pp = \frac{10,000\ m^2 \times \text{number of seeds per plant}}{\text{Product of spacing } (m^2)}$$ (Ajadi, Fagbohun, & Adebooye, 2006)

Table 1: Optimum plant population for some crops

Crop	Spacing	Optimum plant population
Rice	20cm*20cm	300-350 ET/m^2
Wheat	25cm*5cm	250-300 ET/m^2
Maize	75cm*25cm	53,333 plant/ha
Cowpea	120cm*30cm	27777 plant/ha
Cotton	90cm*30cm	37037 plant/ha
Potato	60cm*20cm	83333 plant/ha
Sugarcane	90cm*20cm	55555 plant/ha
Rapeseed	30cm*10cm	333333 plant/ha
Sunflower	60cm*20cm	83333 plant/ha

3.2 Factors affecting plant population

The optimum density of plants varies on all environmental factors. The maximum number of plants/areas depends on the variety, duration, productivity of the soil and water supply (Crickman, 1958).

Table 2: Factors affecting the plant population

Genetic/ Crop Factor	Input/Environmental Factor	Managerial Factor
Seed quality	Irrigation	Method of planting
Size of plant	Nutrient supply	Crop geometry
Elasticity of Plant	Seed rate	Overall Crop husbandry
Forging area	Season	Early/late planting etc
Dry matter Partitioning	Temperature	
Tillering etc	Sunlight	

3.3 Impact of Plant population

3.3.1 Impact of low plant population:

When the planting population is too low, each individual plant may perform at its maximum capacity, but there are not enough plants as a whole to reach the optimum yield. Therefore, the total yield of crops becomes the limiting factor. Also, when there is too much space left between plants, weed growth is promoted, which could increase weeding costs (Mathiew, 2011).

3.3.2 Impact of high plant population

If the plant population is too high, plants may compete with each other, known as intraspecific competition. Under those conditions, the performance of individual plant becomes a limiting factor for maximum crop yield. When there is high plant population, we can observe certain alternations in the growth of plant (Mathiew, 2011). Due to high planting density, the plant height is increased because of the competition for light. The thickness of leaves may be also reduced and leaf geometry is altered due to high population pressure. There is reduction in numbers of ears in indeterminate plants and reduction in size of ear panicles in determinate plants which ultimately leads to decrease in yield.

3.5 Crop response towards plant density

Regarding the crop response towards the plant density (population) two types of crop response has been observed.

a. Asymptotic response:

In several crops like tobacco, leafy vegetables and fodder crops the entire dry matter is utilized as economic product. Hence, in these types of crop the increase in plant population up to a point fetches higher yields but after the peak the response remains constants and there is no increase in yield. Such a response is asymptotic response.

b. Parabolic response

Crops, like rice, wheat, maize and several other increase their yield with increase in plant population up to a point however after the peak point there is reduction in yield with the increases in plant population. Such a response is termed as parabolic response.

3.6 Managing plant population

3.6.1 Seed quality, Size of seeds and seed rate

Quantity of seed sown/unit area, viability and establishment rate decides the planting density. The best seed rate is that which maximizes grain yield. In practice, grain yield hardly changes with further increase in seed rate once the maximum yield is reached. Seed sown above that needed reach the flat part of curve is money wasted. When the more viable seeds are sown per m^2 area proportionately less grow into established plants because adjacent seedlings have to compete more for resources. The number of plants established from a given weight of seed depends on the size of seeds and the percentage of those seeds that are viable and can grow into established plants. The common range of wheat size is 25 to 50 mg and crop establishment varies between 40 and 95 percent of sown seeds depending on soil type, soil moisture, sowing depth, seed quality, disease and insects (FAO, 2005).

Table 3: Effects of seed quality on plant population, seed yield of soybean

Dead seed rate (%)	Planting Density	Seed Yield(kg)
0	143229	3056
10	128900	3219
20	115473	2964
50	72247	2338

Source: (Zaimoglu, Arioglu, & Arslan, 2004)

In this research, dead seed were obtained by treating viable seed with 70°C temperature for 34 hrs. The plant population was higher in 0% dead seed rate and lower yield as compared with 10% dead seed rate representing higher seed rate at 0% dead seed rate resulting in increased competition and lodging of crop but at 10% dead seed rate there was optimum plant population thus efficient utilization of resources but after further increasing the dead seed rate the yield decrease due to low plant population.

3.6.2 Method of sowing

In wheat, the optimum seed rate for drill and broadcast crops are shown as in the figures. Generally, optimum seed rate for broadcast crops can be twice that of drilled crops. Lower yield in Broadcasted is due to rough seedbeds, poor seed covering and poor contact between seed and moist soil which is very good in Drilled.

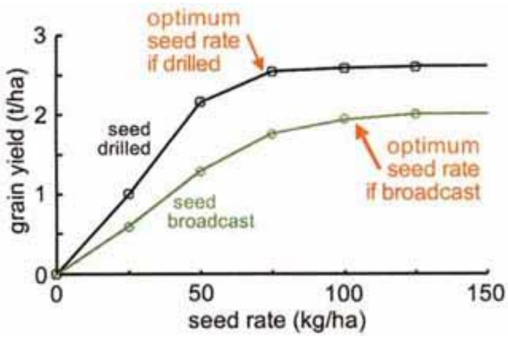

Figure 1: Population establishment under broadcasted and drilled seeding

3.6.3 Sowing depth

In wheat, the maximum yield that could be achieved irrespective of numbers of seed sown is lesser from the deeper planting, down around by 12%. In fact, the number of seeds to plant from the depth to achieve the number of established plants for optimum yield is virtually double that from shallow seeding.

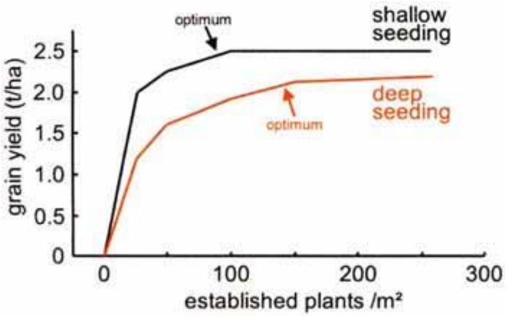

Figure 2: Plant population establishment under shallow and deep seeding

Table 4: Optimum depth of Planting for some crops

Crop	**Depth of sowing(cm)**
Wheat	2-4
Maize	3-5
Cotton	2-4
Sunflower	2-4
Peanut	2-7
Safflower	3-5
Barley	2-4
Linseed	1-2

Source: (Pratley & Stanton, 2002)

The coleoptile length also plays an important role in plant population establishment. If the seed is sown deep the coleoptile cannot reach the soil surface and the fragile shoot must push through the soil without protection. The shoot will often die before it emerges if not protected by the coleoptile. For example wheat varieties vary in their inherent coleoptile length from little as 35mm to over 150 mm. Dwarf and semi – dwarf varieties tend to have shorter coleoptiles that exceed 60mm.

3.6.4 Size of the plant

The volume occupied by the plant at the time of flowering decides the spacing of the crop. Plants of red gram, cotton, sugarcane, etc., occupy larger volume of space in the field compared to rice, wheat, ragi etc. Thus, the highly spaced crop has comparatively lower number of plant population as compared to the narrow spaced one.

3.6.5 Elasticity of the plant

Variation in size or plant between the minimum size of the plant that can produce some economic yield to the maximum size of the plant that can reach under the limited space and resources is the elasticity of the plant. The optimum plant density range is high in indeterminate plants. The elasticity is less and hence the optimum plant density range is small. Generally narrow leaf angle crops and dwarf varieties can be planted more densely than large angled and tall varieties. Mostly, hybrid cultivars are semi-dwarf with narrow leaf angle are planted closely than local cultivars.

3.6.6 Tillering

It is one of properties of cereal crops that affect the number of plants to be maintained in the field. Wheat, rice has high tillering capacity as compare to maize and has upto 15-20% compensation. The yield of sugarcane is higher in ring method due to higher number of tillers. The optimum plant population is that which has optimum space after tiller has emerged in those crops. If the density is high, crowding will reduce the number of tillers produced by each individual (Weiner, 1993).

3.6.7 Time of sowing

The most important factors that influence optimum plant density are day length and temperature. Photosensitive varieties respond to the day length resulting in change in size of the plant. As low temperature retards the growth, higher density is established for quicker ground cover. In agronomy, higher seed rate is used in case of late sown condition to maintain the plant population.

3.6.8 Rainfall/irrigation

Plant density has to be less under rain-fed than irrigated condition. Under higher plant densities, more water is lost through transpiration. Under adequate irrigation or under evenly distributed rainfall conditions, higher plant density is recommended.

3.6.9 Fertilizer application

Higher plant density is necessary to fully utilize higher level of nutrients in the soil to realize higher yield. Nutrient uptake increases with increase in plant density. Higher density under low fertility conditions leads to development of nutrient deficiency symptoms. For example, rice does not respond to plant density without nitrogen application.

3.6.10 Gap Filling/transplanting

After germination, gap filling transplanting of seeds/seeding keeps the plant population as desired. Gap transplanting rice seedling maintaining 20 cm after 20 days also found the plant population compensated (Akbar, Jabran, & Habib, 2007).

Table 5: Effect of Normal Transplanting and Double Transplanting in Rice

Treatment	Grain yield(t/ha)
Double transplanting	5.5
Normal transplanting	5.0

Source: (Satapathy, Singh, Pun, & Rautaray, 2015)

3.6.11 Thinning and defoliation of overpopulated plant density

To decrease the intra crop competition, the thinning is the best method to accompany the double planted crops whereas defoliation is done later stage where there are more canopies in the crop at post vegetative stage. The thinning in mustard is done after 7-15 days of germination but if done 15-30 days results in depletion of yield due to increases competition between plants.

3.6.12 Weeds and plant population

The weeds and plant population has inverse relationship**.** Weeds growth and population in field is more means it lesser the plant populations which can be optimized by proper weed management. Sparse density increases the weed population whereas optimum population keeps the weeds population under control (Donald, 1963)

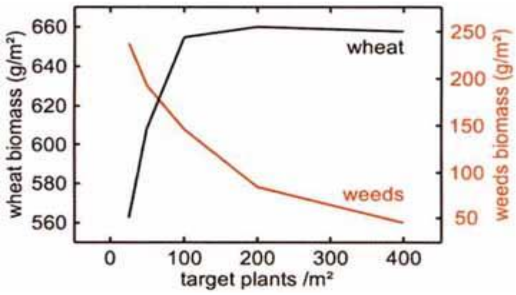

Figure 5: Effects of plant population on crop wheat and weed biomass.

3.6.13 Soil and plant population

Generally, good soil physical property favors good germination of seeds thereby increasing the plant population as desired (Gardner, Laryea, & Unger, 1999), whereas hard and cracked soil surface reduces the plant growth and development. In dry year, at very low bulk densities, yields gradually increase with a slight increase in soil compaction as slightly compacted soil can speed up the rate of seed germination because it promotes good seed-to-soil contact but further increases beyond optimum, yields begin to decline. In wet weather, yields decrease with any increase in compaction as it decreases soil aeration, increasing de-nitrification and increased risk of root diseases (UMN, 2018).

3.6.14 Proper plant pest Management

Insects, diseases and weeds are the major pests of crop that seriously damage the plants in early stage of their life so they cannot withstand properly by intra and inter-specific competition. Preventive and curative measures along with integrated approach can save the plant in early stage and maintain optimal plant population as desired.

3.6.15 Growing of submergence and Drought tolerance variety

Suitable submergence or drought tolerance variety can be used for obtaining optimum plant population. For e.g. Submergence tolerant varieties of rice are Sworna sub-1, Sambha mahasuri sub-1, sheherang sub-1 and drought tolerance variety of rice are Sukkha-1, Sukkha-2, Sukkha-3, Sukkha-4 etc in Nepal.

3.7 Crop plant competition

3.7.1 Interplant competition

When plants are grown in a community, growth is affected by neighboring plant, one plant compete with another for the resources like light, nutrients and water. This competition may modify or changes the growth of crop. For example, plants growing under the high density compete for the light and plant height become taller to receive adequate light interception. The thickness of leaves becomes thinner and vertical to receive more light. Crop like rice, wheat would modify their Tillering behavior and their Tillering number is reduced. Similarly the crop like cotton, pigeon pea may have less number of branches per plant under the high density condition.

3.7.2 Intra plant competition

Intra plant competition is the competition within the plant. When the flower primordia are formed in large numbers, it leads to the formation of large number of inflorescences. The large load for inflorescences leads to the competition for assimilates among the inflorescences and seeds on the same plant. This leads to the intra plant competition. The intra plant competition may be intense at low densities, resulting in a fewer seed and reduced seed size compared with the denser stand. At the widest spacing, both type of competition are absent, during the early stages of growth but at the reproductive stages the intra plant competition may occur because of the large number of reproductive sink developed due to no competition at early stages.

4. Conclusion

Plant density is an important agronomic factor that manipulates the micro- environment of the field and affects the growth, development and yield formation of crops. Inadequate plant stand is one of the most common yield retardants. Competition has negative effect on plant growth which increases with higher plant population. Optimum plant population provides highest crop yield and profit. Number of factors such as crop factors, input factor and management factor affects the optimum plant population. Careful consideration on those factors right from seeding to harvesting, gap filling, defoliation, thinning, weeding must be done for managing plant population and competition.

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