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Estimation Method of Suitable Initial Planting Density

Zhongsheng Guo[1,2,*]

[1]Northwestern A & F University, Yangling, China
[2]Institute of Soil and Water Conservation, CAS & MWR, Yangling, China

[*]**Corresponding Author:** Zhongsheng Guo, Northwestern A & F University, Yangling, China, Tel.: ++86-29-87012411, Fax. ++86-29-8701-2210, E-mail: zhongshenguo@sohu.com

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Abstract

To meet people's yearning for a better life and the needs of agricultural production services, we must use soil water resources sustainably and carry out Agriculture high-quality development. So, we must estimate and take the suitable initial planting density to sow or plant to ensure Plant conservation density in the critical period of plant resources relation regulation reach the vegetation carry capacity to get the maximum yield and beneficial result. However, there are few reports on the estimation method of suitable initial planting density. In this pater, we put forward a method to estimating the suitable initial planting density, and take the perennial plant, caragana in the semiarid loess hilly region and one year plant, pepper in Xunhua, China as an example to determine. The results showing that the estimation method of suitable initial planting density is different for perennial plant caragana and one year plant, we can estimate the suitable initial planting density according to the soil dryness degree of control in the first year in the shrubland of semiarid region. As for a year plant pepper, we can estimate suitable initial planting density according to the area occupied by standard plant with maximum yield and beneficial result in the end of growth season.

Keywords: Agriculture high-quality development; suitable initial planting density; Estimation method; perennial plant; a year plant pepper

Introduction

Since 2017, China development was changed from high-speed development into high-quality development, so, agriculture development had entered the new stage, agriculture high-quality development. The high-quality development of agriculture is to take some measures and methods to make the land produce the maximum output and services to meet people's yearning for a better life and the needs of agricultural production services [1, 2]. However, because overuse of fertilizer, pestcide and introduction of un-native plant species or varieties, initial planting density too high more or too smaller than vegetation carrying capacity in the critical period of plant water relation regulation [1, 2], exotic plant species or varieties changed the plant water relationship, which result in soil degradation and crop failure or waste of soil resources, which are unfavorable for the sustainable utilization of soil resources and crops high-quality production. Therefore, it is necessary to adjust the plant resources relationship and obtain the maximum yield and services to realize the sustainable utilization of soil water resources by plants and crops high--quality management. However, there is not a universally accepted method for estimating Suitable initial planting density. In this paper, we study the method take the caragana shrub in water-limited region, China and pepper in Xun Hua, Qinghai as examples to introduce the method for estimating Suitable initial planting density in water-limited region.

Materials and Methods

Site description

This study was conducted at National high-quality red plum apricot demonstration zone at the Shanghuang Eco-experiment Station in the semiarid Loess hilly region (35°59′- 36°02′ N, 106°26′- 106°30′ E) in Guyuan, Ningxia Hui Autonomous Region of China, Institute of Soil and Water Conservation of Chinese Academy of Sciences, with the altitude of the station ranges from 1,534 m to 1,824 m. Precipitation here is absent in the periods from January to March and from October to December, and the rainfall from June to September makes up more than 70% of the annual precipitation. Mean rainfall measured between 1983 and 2001 was 415.6 mm with a maximum of 635 mm in 1984 and a minimum of 260 mm in 1991. The frost-free season is 152 days. The Huangmian soil consists mainly of loamy porous loess (Calcaric Cambisol, FAO, 1988) with wide distribution in the semiarid hilly region of the Loess Plateau. On June 24, 2002, in the semiarid Loess hilly region with relatively uniform site conditions in the middle of the Heici mountain, the soil was turned, the land was levelled and the caragana was sown, and five areas with an area of 100m were established (20m in long × 5m in wide) of the standard runoff observation field along the slope, the experimental sowing amount is 2.0, 1.5. 1.0, 0.5kg /100m and abandoned land for many years (control). Plot elevation of the experiment site is about 1650m, the slope of the plot is about 8°. In the central area of each runoff field, two aluminum alloy casing were placed 1m apart and along with the slope [2, 3, 4].

The aluminum alloy casing of 4 m neutron meter was used as two repeated moisture observations. The aluminum alloy casing was exposed 10cm and sealed with a rubber cover to reduce the risk of evaporation.

Interference of rainfall to observational data. The soil sample was taken before the aluminum alloy casing was installed, the soil moisture was measured, and then the soil moisture was measured by a neutron meter Compare, analyze and proofread. The measured soil depth is 0-390cm, except that the measuring point 5 cm represents the depth 0-10cm, and the other measuring points represent the soil depth of the measuring point ±10cm. Before the measurement, the neutron meter was calibrated, and the calibration equation was as follows:

$$y = 55.76x + 1.89$$

Where y is the soil volumetric water content and x is the neutron meter reading.

Investigation and Measurement

Rainfall Measurement

Rainfall at the study site was measured with standard rain gauges placed in the center of the National first-class high-quality red plum apricot Demonstration area, which was about 50 m from the Shanghuang Eco-experiment weather station, as a part of Guyuan Eco-experiment weather station under Institute of soil and water conservation of Chinese Academy of Sciences. The study also included the determination of the soil moisture con-tent, plant root distributions, and other plant growth parameters [4].

Physical Characteristics of Soil

The experimental plots located in the sowing caragana shrub in 20o2. The sampling pits (soil profile) was dug in red plum apricot forest at the experimental site for investigating soil profile and sampling purposes, whose dimensions were $1m^2 \times 4$ m depth on the red plum apricot forest in April, 13, 2018. The undisturbed soil samples were collected for 3 times at the depth of 0 to 5, 20 to 25, 40 to 45, 80 to 85, 120 to 125, 160 to 165, 200 to 205, 240 to 245 and 395 to 400 cm with cutting rings (a 5 cm in high, 5 cm in inner diameter and 100 cm3 in cubage). At the same time, the disturbed soil of about 100g at each depth was collected for determination of soil structure at the State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau.

Cutting ring was used to measure the bulk density, total porosity, capillary porosity, saturation moisture content. The core samples (undisturbed soil sample) collected were used with cutting rings to measure the soil bulk density, capillary porosity and noncapillary porosity. The bulk density was determined by oven-drying the cores at 105-110℃, and the total porosity was calculated as 1-bulk density/soil particles density, assuming that the density of soil particles was $2.65g/cm^3$. Noncapillary porosity was the difference between total porosity and capillary porosity. Soil particles were measured with master sizer 2000 laser particle analyzer and grain size was graded on the USA standard. Soil water contents at different soil suctions (0.01, 0.02, 0.04, 0.06, 0.08, 0.1, 0.2, 0.4, 0.6 bar, 1 bar = 0.1×10^6 Pa) were measured by a HITACHI centrifuge, made by Instrument Co., Jappan. Because Huangmian soil had been contracted when measuring with a centrifuge, the researchers measured the shrink amount of soil samples in the cutting ring by vernier callipers at different soil suctions and then calculated the volumetric soil water content.

Soil Water Measurement

Two holes with 5.3 cm in diameter were made by holesaw in the place about 100 cm apart from the two 4-m long aluminum access pipes in the plot were placed in the holes with an interval of 1 m between them on the 13 Aprill,2002. Another two holes with 5.3 cm in diameter were made by holesaw in the middle of the runoff, about 2 m away from the tree base (center) to the exterior margin of the canopy in the 16-year-old caragana tree planted in the bench terrace in 1986. The interspaces between access pipes and soil were filled with some fine earth in case water might flow through the interspaces. A neutron probe, CNC503A (DR), made by Beijing Nuclear Instrument Co., China, was used for long-term monitoring of the field soil water content because of its high precision in situ [3]. Before measuring the volumetric soil water content (VSWC), the neutron probe was calibrated for the soil in the study area by using standard methods (Hauser 1984). The calibration equation for this soil at the site is $y = 55.76 x + 1.89$, where y is VSWC, and x is the ratio of the neutron count in the soil to the standard count. The measuring depth ranged from 0 to 400 cm in the period from April to October, in 2018 and 2019. Measurements were made with 15-day intervals in time and 20 cm intervals in depth. Measurements were made every 15 days to a depth of 4 m in increments of 20 cm starting at the 5 cm depth. When measuring soil water content at different soil depth, first put the probe into the aluminum access pipes and change the measuring line of the neutron probe to confirm the weather or not the soil depth equal planned depth of determination according to the display device of soil depth. Secondly, press the start button and then read and record the numbers of soil water content at different soil depth on the display screen of the neutron probe. The soil water content obtained for each measuring depth was taken to be representative for the soil layer that included the measuring point ± 10 cm depth, apart from that for the 5 cm depth, which was taken to represent the 0 to 10 cm soil. The measurements were also made before and after each rain event in the caragana shrub.

Plant Growth Measurement

In September 2002, the plant densities of 0-year-old caragana seedlings were investigated by transplanting method. During the survey in 2002, two transect lines were selected along the long axis of the plot in the middle of each plot (1m away from the two edges, respectively). Starting from 5cm, a quadrat is laid every 1m, and each is 1m×1m. A total of 18 quadrats were investigated in the district, and the sample volume was 1m × 1m.

During the growing season, the growth of Caragana and soil moisture in different density profiles were measured throughout the year. During the observation period. The base diameter and plant height of Caragana were measured every 15 days during the growing season. The base diameter is measured with vernier calipers, and the marked position shall prevail. The height of the plant is measured with a meter rule, based on the height from the surface to the top bud [3, 5].

Main equation

Estimation of Infiltration Depth

If you measure the change of soil water with soil depth before a rain event according to the weather report, and then measure the change of soil water with soil depth after the rain event, draft and compare the figure of the change of soil water content with soil depth at two different time, we can get the infiltration depth for one rain event and the soil water supply for one rain event. If you measure the change of soil water with soil depth in a long term, you will get the maximum infiltration depth [4, 6, 7].

Estimate of Soil Water Consume Depth Used by Plants

If you measure the change of soil water with soil depth before, draft and compare the figure of the change of soil water content with soil depth at two different time in the same vegetation type, such as measured on the sowing date measured on 24, June and the 1 November, 2002, you can get the Soil water consume depth used by plants. Soil water consume depth used by plants is the distance from the cross point of the two vertical curves to the surface land [4, 6, 7].

Soil Water Resources

$$SWR = 10\int_{0}^{n} d\theta X h_i dh$$

Here, SWR is soil water resources in mm. dθ is volumetric soil water content in %. The h_i is the soil thickness at ith soil layer in cm. The i is the number of soil layer.

Estimation of Optimal Initial Planting Density

Estimation of optimal initial planting density for perennial plant

Optimal initial planting density for perennial plant is the maximum initial planting density when the reduction of soil water resources equal or smaller than the waste land in one year.

Optimal initial planting density for one year plant

$PD = S/s$

Here, the symbol S is the total area in a square meter or ha, S is the individual crown area of the standard plant in square meter.

Result

The Sowing Seed and the Plant Density Relation

The relationship between sowing amount and plant density is closed, see the relationship between sowing amount and plant density in caragana shrub land, shown in Table 1 and figure 1. From the table 1 and figure 1, we can see that the plant density increases with sowing amount. But the increment in plant density reduces with sowing seed when the sowing amount is more than 1.5 kg per 100 m^2, the increment in plant density almost stops.

Table 1: The relationship between sowing amount and plant density in caragana shrubland

Iterm	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Control
sowing amount(kg/100 m^2)	2.0	1.5	1.0	0.5	0
caragana density(shrub/100m^2)	6700	6500	5100	2500	0

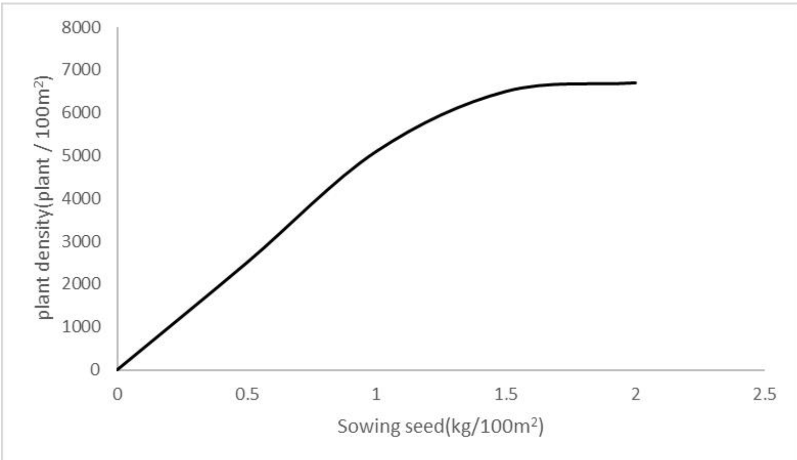

Figure 1: The change of plant density with sowing amount in 0-year caragana shrub land

The Plant Density and Growth Relation

The relationship between plant density and growth is shown in Figure 2. From the figure 2, we can see that the height growth and diameter growth increase with sowing amount. But the increment in height growth and diameter growth almost stops with sowing seed when the sowing amount is more than 0.5 kg per 100 m^2 [6].

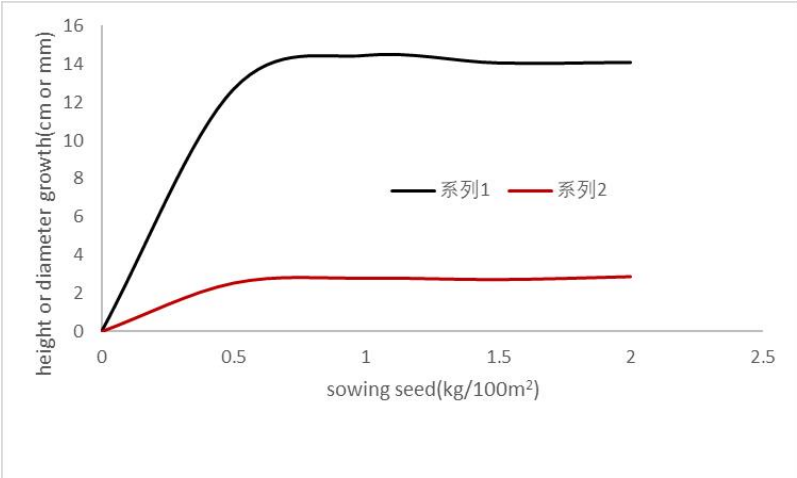

Figure 2: The change of height growth (Black line) and diameter growth (Red line) with sowing seed in 0-year-old caragana shrub land

Estimation Method of Suitable Initial Planting Density in Water-Restricted Areas

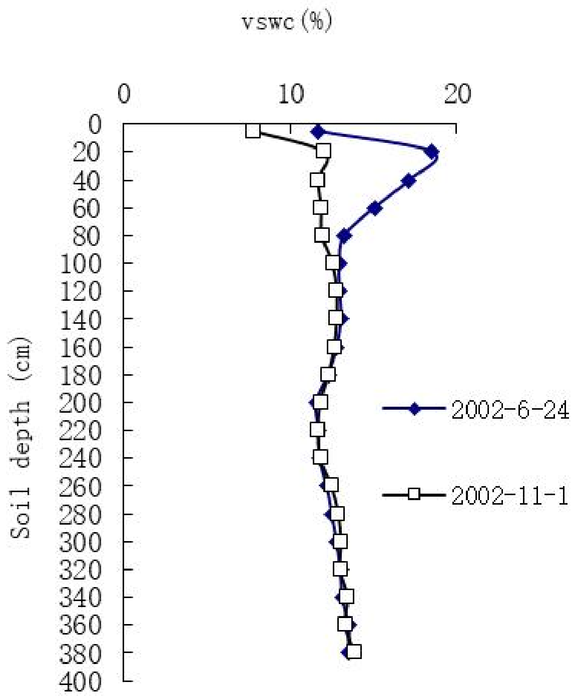

Figure 3: Soil water consume depth used by plants from 24 June to 1 November, 2002 in 0-year-old caragana shrub land in Guyuan, China

According to comparing the change of soil water content with soil depth on the sowing date on 24, June, and the 1 November, 2002, we can get the Soil water consume depth used by plants, see figure 3.From the figure 3, we can see that is the distance from the cross point of the two vertical curves to the surface land. Soil water consume depth used by plants in 1.5 plot is 170cm.and the 390 cm in 2.0 plot, which is more than the maximum infiltration depth [4, 6, 7]. We can take the Reduction of soil water resources as a standard to estimate the suitable initial planting density, see table 2. Frome the Table 2, we can see the suitable initial planting density is the plant density in 1.5 plot, 6500 tree per 100 m^2. The caragana with the suitable initial planting density in 2003-2006 grow well and the benefit of soil water conservation is great.

Table 2: The relationship between Sowing seed and Reduction of soil water resources

Sowing seed (kg per 100 m^2)	2.0	1.5	1.0	0.5	0
initial planting density (plant/100m^2)	6700	6500	5100	2500	0
Reduction of soil water resources (mm)	72.335	51.3	42.83	22.765	53.67

As for a year plant, pepper, we can take the pepper with maximum yield and benefit with the heigh of 60 cm and crown area of 0.12m^2 (30cm×40cm) as a standard plant to estimate the suitable initial planting density. For example on September 26, 2023, we investigate the fresh yield per pepper in semiarid region (Xunhua, China), I found an pepper with maximum yield and benefit with the heigh of 50 cm and crown of 30cm×40cm, maximum yield is 400 k per plant. According to the standard plant, the equation of the suitable initial planting density of pepper is 1 m^2 square divided by 0.12m^2, the result is 8 plants per m^2, see the figure 4.

Discussion

The high-quality development of agriculture is to take some measures and methods to make the land produce the maximum output and services to meet people's yearning for a better life and the needs of agricultural production services [2]. In vegetation afforestation or agriculture production, planting density is an important index. If planting density is too high more than the suitable initial planting density, the competition among plant or trees for light, soil nutrients and soil water, etc.) will be intense, which will lead to tree growth limitation[5]. If the afforestation density is lower than the suitable initial planting density, although the competition between trees will be reduced, some tree species will grow slowly, and it will cause problems such as slow closure of plantation and low overall stock in forest, which will affect the afforestation effect. So, to carry out the high-quality development of Agriculture, we must estimate the suitable initial planting density and ensure plant grow well and get the maximum yield and service.

Because the cultivating period of getting into maximum yield and benefit for perennial plant and a year plant is different, we should take different method to get the suitable initial planting density. For perennial plant such as caragana in the water-limited regions, soil water is the most important Figure 4.

Figure 4

The standard plant for one year plant, pepper with maximum yield and benefit in Xunhua, Qinghai, China. Author teaches the local people to estimate the suitable initial planting density according to the crown size (left photo) with maximum yield and benefits (Right photo) on September 27,2023. This is a standard plant with the maximum yield and benefit factor influencing plant growth, we can estimate the suitable initial planting density according to the soil dryness degree of control in 0-year-old plant, such as caragana shrub. Due to the dry climate in 2002, the precipitation was slightly lower than the average annual rainfall and there are different degrees of drought appeared in the soil profile of Caragana seedling shrub with different sowing amounts and plant density. In the 0-390cm soil depth, soil water resources decreased by 72.3mm in high density 2.0 plot, 51.3 mm in the 1.5 plot, 53.7mm in the control plot, 42.8mm in the 1.0 plot and 22.8mm in the 0.5 plot. If we take the 53.67mm as common, then we can take the Reduction of soil water resources of 51.3 mm as a normal reduction. The suitable initial planting density of caragana is 6500 shrubs per 100^2, which will ensure the 2 to 4-year-old caragana with the suitable initial planting density grow well compared with other different caragana. For a year plant pepper, we can take standard plant with maximum yield and benefit as an example to estimate the suitable initial planting density and get the maximum yield and beneficial result. The suitable initial planting density equation for pepper is the total square of 1 m^2 divided by a single standard planting area. In water and nutrient rich regions, we can estimate the suitable initial planting density according to the canopy development speed and the adult plantation planting design to estimate the suitable initial planting density.

Conclusion

Now, we have entered a new time of high-quality development, agriculture development must carry out high-quality development. To carry out Agriculture high-quality development, we must select better plant species and varieties, take the suitable initial planting density and effective measures to ensure plant grow well and get maximum yield and beneficial result. In this paper, we take the perennial plant caragana and one year plant pepper as examples, introduce the method of estimating suitable initial planting density. The suitable initial planting density can be estimated according to the soil dryness degree of control of one year plant, and as for a year plant pepper, we can estimate suitable initial planting density according to the standard plant cover area with maximum yield and beneficial result. The method is simple and the result is good for practice in Agriculture high-quality development.

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