Australian Journal of Crop Science AJCS

AJCS 16(07):941-948 (2022) ISSN:1835-2707
doi: 10.21475/ajcs.22.16.07.p3604

The density and sowing time of buckwheat in organic and conventional growing system

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Abstract

The adjustment of buckwheat density and sowing time in an organic growing system guarantees satisfactory productivity with better environmental quality. The objective of the study is to adjust the sowing density and the best growing season of buckwheat, comparing the organic and conventional growing system. In the study, two experiments were conducted in 2017 and 2018. Experiment one, in a randomized block design with eight replications in a 4 x 2 factorial, for sowing density (40, 80, 120 and 160 kg ha^{-1}) and growing location (Augusto Pestana and Três de Maio, RS, Brazil), respectively. Experiment two, in a randomized block design in a 2 x 2 factorial with eight replications, for sowing time (September and December) and growing system (conventional and organic), respectively, carried out in Augusto Pestana, RS. Grain yield and other characters of agronomic interest of the species were evaluated, with means analysis and regression adjustment. The sowing density around 110 kg ha^{-1} brings benefits in the buckwheat growing in reaching maximum grain yield in conventional and organic systems. Sowing in September and December is possible regardless of the production system. However, grain yield is maximized under the milder temperature conditions of September. The grain yield in an organic system, although statistically inferior to the conventional one, proves to be advantageous due to the reduced variation in yield due to add value of the product without the use of pesticides and fertilizers.

Keywords: *Fagopyrum esculentum* L; food safety; production systems; satisfactory productivity; sustainability.
Abbreviations: FY_favorable year; GY_grain yield; UY_ unfavorable year; DEF_days from emergence to flowering; DFM_ days from flowering to maturity; DEM_days from emergence to maturity; PH_plant height; TGM_thousand grain mass; HM_hectoliter mass.

Introduction

Nowadays, great interest has been given to foods with high nutritional value and present bioactive ingredients without the presence of gluten, facilitating healthy weight loss for all types of consumers (Rosell, 2013; Pintado et al., 2016). In this perspective, buckwheat presents itself as an alternative, constituting flours with high nutritional and nutraceutical quality without the presence of gluten (Gonçalves et al., 2016; Nunes et al., 2019). Allied to this, the use of high biological quality species, qualifying more sustainable production systems, is essential for reducing environmental impacts on water, air, soil and food (Carvalho and Szlafsztein, 2019; Link et al., 2019).
For acceptable yields with adequate soil biomass coverage, sowing density adjustment should be considered, especially in buckwheat, where the recommendation shows a strong variation of 50 to 100 kg of seeds per hectare (Juszczak et al., 2011; Gavrić et al., 2017). Densities that promote rapid soil coverage and protection through canopy adjustment favor better use of water, light and nutrients together with more effective control over the evolution of species considered invasive, reducing or eliminating the use of agrochemicals (Fleck et al., 2009; Lamego et al., 2013).
Appropriate sowing times must also be observed, providing adequate ecological conditions in defining a zoning for the species, facilitating the development and expression of yield components (Kalinova et al., 2005; Jung et al., 2015). In the literature, although buckwheat shows a wide variety of climate and soil with a fast growing cycle (Arduini et al., 2016; Siracusa et al., 2017), it needs more concentrated research considering the edaphoclimatic conditions of southern Brazil. In this perspective, a zoning should be considered seeking to aggregate satisfactory yields with a

reduction or absence of fertilizers and herbicides (Sobhani et al., 2012; Joshi et al., 2019).

Studies have shown the possibility of producing high quality flours with a reduction or total absence of pesticides and fertilizers, in the promotion of an increasingly organic agriculture (Lopez et al., 2017; Estrada et al., 2019), which can be obtained with satisfactory yields and added value of the product for commercialization (Campbell, 1997; Siracusa et al., 2017). The difference and particularities between organic and conventional systems is well recognized around the world and has become one of the main focuses of international debates in the field (Ferreira and Coelho, 2017; Tricase et al., 2018). In this context, there is a growing search for foods with higher nutritional quality and managements that ensure yield with food and environmental security (Teixeira et al., 2012; Pereira et al., 2017).

Buckwheat has been standing out as a species adjusted to organic cultivation, ensuring yields under more restrictive growing conditions (Zhu, 2016; Ge and Wang, 2020). Thus, research aimed at the development of managements linked to the adjustment of sowing density and growing season, comparing the conventional and organic production system, can make the growing of buckwheat viable in a more sustainable production condition. It is understood that this perspective is in tune with the UN's global goals for sustainable development, with emphasis on the eradication of hunger and sustainable production and consumption.

Given the importance of research on alternative production systems and the scarcity of information on adequate sowing density and the best growing season for buckwheat in different production systems, the following hypotheses were developed: i) higher sowing densities maximize the buckwheat yield in conventional and organic growing systems; ii) the best sowing time for the cultivation of buckwheat coincides with periods of milder temperatures; and iii) There are economic and environmental advantages of the organic farming system over traditional farming. In order to meet these hypotheses, the objective of the study is to adjust the sowing density and the best growing season of buckwheat comparing the organic and conventional growing system.

Results and Discussion

Means and regression analysis

The analysis of variance (not shown) was performed considering the individuality of the place and year of cultivation, starting to simplify the results, regardless of the absence and presence of interaction. In table 1 of means, it was observed that the increase in sowing density promoted an increase in grain yield up to a limit, regardless of year and location conditions. In Augusto Pestana, in 2017, the point of highest yield was with the use of 120 kg ha^{-1} of seeds. In 2018, the points of 80 and 120 kg ha^{-1} of seeds showed the highest yields, not differing from each other. In Três de Maio, regardless of the crop season, the 120 kg ha^{-1} seed point showed the highest yields. The results obtained show that densities higher than the recommendation bring significant increases in buckwheat yield, indicating the need to change the recommendation in these study sites. Also in table 1, it is highlighted that the thousand grain mass and the hectoliter mass show changes in promoting the specific mass by increasing the density of cultivation. Regardless of year and location, the increase in sowing density promotes a significant increase in stature and reduction in the cycle, mainly due to changes that occur on the days from emergence to flowering, as the time from flowering to maturation has not changed.

Tables 2 and 3 show the values of maximum technical efficiency of grain yield as a function of sowing density, with simulation on the other agronomic characters from the optimum dose obtained. Therefore, the ideal density value was included in the parameter (x) of each equation that represents the behavior of each variable for expression predictability. Thus, in Augusto Pestana in 2017 (Table 2), the ideal sowing density for grain yield was obtained with 115 kg ha^{-1} of seeds. The linear decreasing behavior observed for the variables days from emergence to flowering and days from emergence to maturity indicated values of 33 and 91 days, respectively, using the optimal density. The increasing linear function for plant height shows a tendency to reach 107 cm with the adjusted density.

In 2018, the adjusted density was obtained with 103 kg ha^{-1} of seeds. In this condition, there is a certain stability of the thousand grain mass and hectoliter mass in the simulation with the optimal density, however, in the other variables of cycle and height, there is a significant increase in time in the expression of phenological stages, as well as greater height plant, confirming the information that contribute to a more favorable crop season for cultivation.

In table 3, in Três de Maio in 2017, the density adjusted to maximum grain yield was around 122 kg ha^{-1} of seeds. This year, the days from emergence to flowering, from emergence to maturity also confirmed decreasing linear behavior as a function of sowing densities, with simulations of the optimum point that register 34 and 90 days, respectively. In terms of the significant linear function obtained for plant height, the predictability of reaching 101 cm is evident. In 2018, as occurred in Augusto Pestana, the adjusted sowing density was lower, with 107 kg ha^{-1} of seeds at the maximum expression of grain yield. All other variables analyzed showed a linear increasing behavior for the thousand grain mass, hectoliter mass and plant height and with a linear function of reduction of those that define the development cycle. Gavric et al. (2018) when evaluating the grain yield of buckwheat at sowing densities of 50, 80 and 100 kg ha^{-1}, obtained the highest grain yields at the highest density, with 810, 1,060 and 1430 kg ha^{-1}, respectively, a similar behavior to that observed in this research. In general, information from brochures and technical bulletins has been recommending cultivation with a sowing density of 40 to 80 kg ha^{-1}. In the literature, there are few studies that specifically analyze the grain yield of buckwheat as a function of sowing density. Studies conducted by Popovic et al. (2013), Inamullah et al. (2012) and Domingos and Bilsborrow (2021) using densities of 60 kg ha^{-1}, 70 kg ha^{-1} and 90 kg ha^{-1}, obtained grain yields of 1300, 1320, and 1600 kg ha^{-1}, respectively, results much lower than those obtained in this study for 2018.

Classification of agricultural year

In general, during the September 2017 growing cycle, an average air temperature of 21 °C was observed, ranging from 6 to 35 °C, and rainfall of 160mm. In December, the average temperature was 26 °C, ranging from 13 to 38 °C and rainfall with 135mm. In September 2018, the average air temperature was 20 °C, ranging from 5 to 34 °C and 130 mm of rainfall. In December 2018, an average air temperature of 23 °C and a range of 8 to 37 °C was recorded, with 92 mm of

Table 1. Mean of grain yield and other traits of agronomic interest in buckwheat.

Densities	GY	TGM	HM	DEF	DFM	DEM	PH
(kg ha^{-1})	(kg ha^{-1})	(g)	(kg hl^{-1})	(days)	(days)	(days)	(cm)
Augusto Pestana, RS							
2017							
40	675 c	26.5 a	68 a	37 a	59 a	96 a	93 c
80	1046 b	26.7 a	67 a	36 a	58 a	93 b	104 b
120	1149 a	27.0 a	67 a	32 b	58 a	90 c	104 b
160	987 b	26.7 a	67 a	30 b	58 a	88 d	117 a
2018							
40	1193 c	25.8 b	63 b	43 a	53 c	96 a	112 b
80	2172 a	27.6 a	64 b	41 b	54 a	96 a	126 a
120	2006 a	29.4 a	67 a	39 c	53 b	92 b	131 a
160	1495 b	29.5 a	68 a	37 d	51 d	89 c	138 a
Três de Maio, RS							
2017							
40	700 c	26.7 a	66 a	38 a	57 a	95 a	84 c
80	937 b	26.5 a	65 a	37 a	56 a	93 b	95 b
120	1224 a	26.5 a	66 a	34 b	56 a	90 c	104 a
160	1013 b	26.2 a	66 a	32 c	55 a	88 d	106 a
2018							
40	1504 d	25.6 b	63 c	42 a	54 a	97 a	111 b
80	2144 b	26.0 b	64 c	42 a	54 a	96 a	120 b
120	2432 a	28.2 a	66 b	39 b	53 a	92 b	128 a
160	1807 d	29.5 a	69 a	36 c	53 a	89 c	132 a

GY: Grain yield; TGM: Thousando grain mass; HM: Hectoliter mass; DEF: Days from emergence to flowering; DFM: Days from flowering to maturity; DEM: Days from emergence to maturity; PH: Plant height.

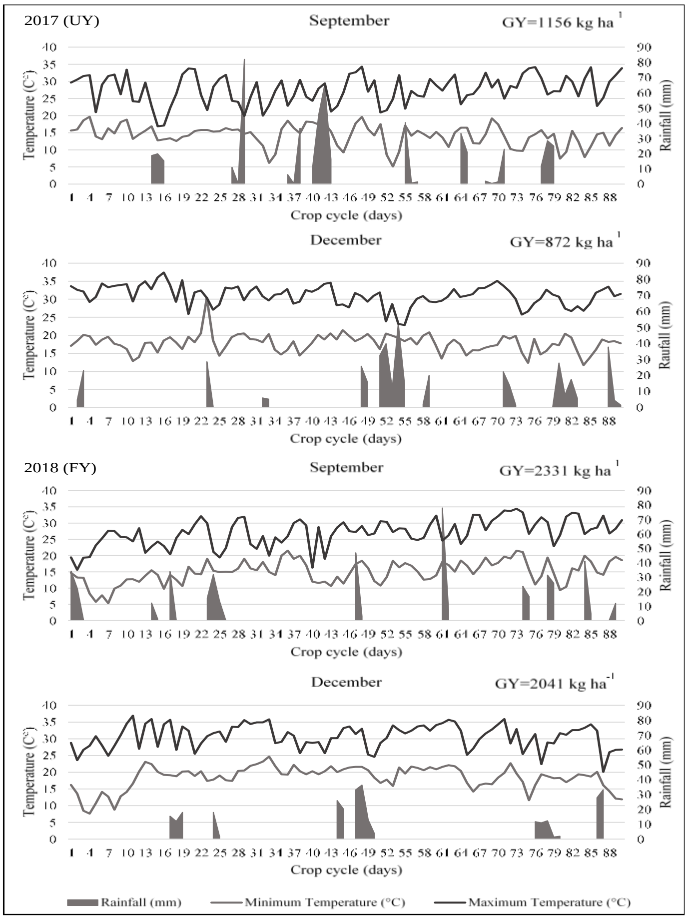

Fig 1. Data of rainfall and daily minimum and maximum temperature during the buckwheat growing cycle, in the years 2017 and 2018. Data obtained from the meteorological station located at the Regional Institute for Rural Development/IRDeR/UNIJUÍ, 2020. UY= unfavorable year; FY=favorable year; GY=grain yield.

Table 2. Regression of buckwheat agronomic indicators as a function of sowing density in Augusto Pestana, RS.

Variable	Model	Regression $y = a \pm bx \pm cx^2$	R^2	$bi_{(x)}$	MTE (kg ha^{-1})	$y_{Estimated}$
2017						
GY	L	$704 + 2.601x$	14	*	(115)	1151
(kg ha^{-1})	Q	$37 + 19.270x – 0.08335x^2$	99	*		
TGM	L	$26 + 0.002x$	10	ns		26
(g)	Q	$26 + 0.018x – 0.00007x^2$	70	ns		
HM	L	$67 – 0.001x$	48	ns		67
(kg hl^{-1})	Q	$67 – 0.024x + 0.00011x^2$	55	ns		
DEF	L	$40 – 0.061x$	96	*		33
(days)	Q	$40 – 0.045x – 0.00007x^2$	94	ns		
DFM	L	$59 – 0.009x$	40	ns		59
(days)	Q	$59 – 0.048x + 0.00019x^2$	79	ns		
DEM	L	$99 – 0.070x$	98	*		91
(days)	Q	$99 – 0.094x + 0.00011x^2$	98	ns		
PH	L	$86 + 0.178x$	85	*		107
(cm)	Q	$86 + 0.100x + 0.00039x^2$	72	ns		
2018						
GY	L	$1531 + 1.850x$	43	ns	(103)	2182
(kg ha^{-1})	Q	$-331 + 48.40x – 0.23301x^2$	84	*		
TGM	L	$24 + 0.032x$	86	*		24
(g)	Q	$24 + 0.083x – 0.00025x^2$	94	ns		
MH	L	$61 + 0.046x$	95	*		61
(kg hl^{-1})	Q	$61 + 0.062x – 0.00007x^2$	92	ns		
DEF	L	$75 – 0.052x$	99	*		75
(days)	Q	$75 – 0.068x + 0.00007x^2$	99	ns		
DFM	L	$54 – 0.012x$	39	ns		54
(days)	Q	$54 + 0.096x – 0.00054x^2$	79	*		
DEM	L	$100 – 0.063x$	86	*		100
(days)	Q	$100 + 0.038x – 0.00050x^2$	95	ns		
PH	L	$106 + 0.211x$	91	*		106
(cm)	Q	$106 + 0.445x – 0.00117x^2$	94	ns		

L: Linear; Q: Quadratic; R^2: Coefficient of determination; P $bi_{(x)}$ – Probability of the slope parameter; * - Significance of the slope parameter at 5% probability of error by the t test; ns - Not significant at 5% probability of error; MTE: Maximum technical efficiency; GY: Grain yield; TGM: Thousand grain mass; HM: Hectoliter mass; DEF: Days from emergence to flowering; DFM: Days from flowering to maturity; DEM: Days from emergence to maturity; PH: Plant height

Table 3. Regression of buckwheat agronomic indicators as a function of sowing density in Três de Maio, RS.

Variable	Model	Regression $y = a \pm bx \pm cx^2$	R^2	$bi_{(x)}$	MTE (kg ha^{-1})	$y_{Estimated}$
2017						
GY	L	$661 + 3.069x$	30	*	(122)	1141
(kg ha^{-1})	Q	$101 + 17.07x – 0.07003x^2$	67	*		
TGM	L	$26 – 0.003x$	85	ns		26
(g)	Q	$26 – 0.003x – 0.00001x^2$	70	ns		
HM	L	$66 – 0.001x$	49	ns		66
(kg hl^{-1})	Q	$66 – 0.055x + 0.00027x^2$	62	ns		
DEF	L	$40 – 0.049x$	92	*		34
(days)	Q	$40 – 0.025x – 0.00011x^2$	86	ns		
DFM	L	$57 – 0.015x$	70	ns		57
(days)	Q	$57 – 0.046x + 0.00015x^2$	73	ns		
DEM	L	$98 – 0.064x$	98	*		90
(days)	Q	$98 – 0.072x + 0.00039x^2$	97	ns		
PH	L	$78 + 0.188x$	89	*		101
(cm)	Q	$67 + 0.471x – 0.00140x^2$	97	ns		
2018						
GY	L	$1673 + 2.990x$	27	ns	(107)	2389
(kg ha^{-1})	Q	$91 + 42.53x – 0.19773x^2$	90	*		
TGM	L	$23 + 0.034x$	92	*		27
(g)	Q	$25 + 0.005x + 0.00014x^2$	90	ns		
HM	L	$61 + 0.048x$	92	*		66

(kg hl^{-1})	Q	$63 - 0.0137x + 0.00031x^2$	99	ns	
DEF	L	$45 - 0.055x$	82	*	39
(days)	Q	$41 + 0.054x - 0.00054x^2$	99	ns	
DFM	L	$55 - 0.015x$	70	*	53
(days)	Q	$55 - 0.015x + 0.00001x^2$	40	ns	
DEM	L	$100 - 0.071x$	86	*	92
(days)	Q	$96 + 0.039x - 0.00054x^2$	94	ns	
PH	L	$104 + 0.184x$	96	*	124
(cm)	Q	$98 + 0.332x - 0.00074x^2$	99	ns	

L: Linear; Q: Quadratic; R^2: Coefficient of determination; P $bi_{(x)}$ – Probability of the slope parameter; * - Significance of the slope parameter at 5% probability of error by the t test; ns - Not significant at 5% probability of error; MTE: Maximum technical efficiency; GY: Grain yield; TGM: Thousand grain mass; HM: Hectoliter mass; DEF: Days from emergence to flowering; DFM: Days from flowering to maturity; DEM: Days from emergence to maturity; PH: Plant height

Table 4. Sowing times of buckwheat under conventional and organic systems.

Season	GY	TGM	MH	DEF	DFM	DEM	PH
	(kg ha^{-1})	(g)	(kg hl^{-1})	(days)	(days)	(days)	(cm)
	Conventional system						
	2017 (UY)						
September	1320 a	27 a	66 a	34 a	56 a	90 a	120 a
December	1048 b	27 a	66 a	37 a	56 a	93 a	105 b
	2018 (FY)						
September	2432 a	28 a	67 a	40 a	53 a	93 a	135 a
December	2144 b	26 a	65 a	42 a	55 a	97 a	120 b
Mean	1736 A	27 A	66 A	38 A	55 A	94 A	120 A
	Organic system						
	2017 (UY)						
September	992 a	26 a	68 a	35 a	55 a	90 a	112 a
December	697 b	26 a	68 a	34 a	59 a	93 a	94 b
	2018 (FY)						
September	2230 a	29 a	68 a	38 a	52 a	90 a	125 a
December	1939 b	26 a	65 a	40 a	53 a	93 a	112 b
Mean	1464 B	27 A	67 A	37 A	55 A	92 A	111 A

GY: Grain yield; TGM: Thousand grain mass; HM: Hectoliter mass; DEF: Days from emergence to flowering; DFM: Days from flowering to maturity; DEM: Days from emergence to maturity; PH: Plant height; UY=unfavorable year; FY=favorable year. Means followed by the same lowercase letters constitute a statistically homogeneous group by the Scott & Knott test at 5% probability of error. Means followed by the same capital letters constitute a statistically homogeneous group by the Scott & Knott test at 5% probability of error.

rainfall. In Figure 1, when analyzing rainfall between seasons, more significant volumes of rainfall were observed in 2017, with concentration in certain periods of the cycle. On the other hand, although rainfall accumulated in 2018 was lower, it showed a more regular distribution throughout the cycle, a condition that resulted in an increase of 1000 kg ha^{-1} in grain yield. Regardless of the crop season, the lowest temperature values were verified in the month of September, generating an increase of 300 kg ha^{-1} in the crop's grain yield. The reflection of weather conditions on grain yield characterizes 2017 as an unfavorable year for growing and 2018 as favorable, with greater interference in yield due to the distribution and volume of rainfall in relation to air temperature.

The results obtained in this study show that although buckwheat is a species with a reduced cycle (around 90 days), it shows resilience to the condition of less rainfall, possibly linked to the species' indeterminate growth habit, which contributes to its production ability and range of expression of reproductive structures. Arenhardt et al. (2015), highlight that long period of rain during the cycle reduce the efficiency of light and nutrient use for photosynthesis, interfering with the development, yield and quality of grains during harvest (Castro et al., 2012). Air temperature is also decisive for the development of yield, acting as a catalyst for biological processes, which is why plants require a minimum and maximum temperature for normal physiological activities (Guarienti et al., 2004). In general, milder temperatures and adequate availability of solar radiation associated with the distribution of rainfall to supply plants with water stored in the soil favor the expression of production components. It is noteworthy that rains in large quantities and intensity affect production, whether by leaching of nutrients, erosion, lodging and less efficient use of light to photosynthesis (Marolli et al., 2017).

In Table 4 of the sowing time in the growing systems, the conventional system in September provides the highest yields and plant height, regardless of the year. When observing the favorable and unfavorable conditions for growing, it is clear that 2018 presents the highest averages in most of the analyzed variables, depending on the meteorological benefits offered. The growing of buckwheat in an organic system (Table 4) also shows higher average grain yield and plant height at sowing in September. Although no statistical differences were observed between the thousand grain mass and the hectoliter mass, in 2018 (favorable to growing), they had higher averages when sowing was carried out in September.

Optimizing planting density is an important step to improve grain production. In studies carried out in this same perspective, they show that the variation in yield by plant population is associated with the potential of the genotype to produce biomass per area, since sowing density directly influences the number of inflorescences produced per area (Castro et al., 2012). Allied to this, rapid ground cover by canopy adjustment can favor better use of light and nutrients, providing more effective control over the evolution of species considered invasive (Lamego et al., 2013; Kumari and Chaudhary, 2020). The strong variation in yield is also associated with the great variability of growing conditions, with the season being the biggest contributing factor (Storck et al., 2014; Arenhardt et al., 2015). Therefore, years of favorable and unfavorable climate change the efficiency of use of natural resources and management technologies on plant yield (Mantai et al., 2015; Arenhardt et al., 2015).

This study brings a great contribution to advances in the production systems of this species, since, in several analyzed studies, an exact recommendation for sowing was not found. Experiments carried out in Brazil such as the one by Klein et al. (2010), with populations above 1,000,000 plants, obtained good results for biomass production. On the other hand, in the Rio Preto region of Brasília, growers do not go far beyond 500,000 plants due to the difficulty of mechanized harvesting caused by high rates of falling over. Rereading the experiment data, it can be seen that in populations above 800,000 plants the diameter becomes noticeably smaller. Saracen is naturally a plant subject to lodging, so even if high densities do not harm biomass production, this situation can hinder the use of mechanical harvesting or a high waste in case of harvesting plants for silage or direct grazing of animals (Furlan et al., 2006). It is worth adding that as a plant of indeterminate growth, buckwheat plants have a succulent stem until just before maturation, making them susceptible to lodging. Furthermore, the changes that occur in the growth and development of plants are the result of variations in environmental conditions, such as water, temperature, intensity and light source (Nam et al., 2018). Fang et al. (2018) evaluating different sowing densities in buckwheat with 60, 90 and 120 plants m^2, showed that higher densities were more efficient in maximizing crop yield.

In addition to adjusting sowing density, the application of fertilizers to obtain an optimal yield is essential (Salehi et al., 2017). However, the use of mineral fertilizers can harm the environment and soil health, causing soil acidification, depletion of organic matter, severe groundwater pollution, eutrophication of surface water, and can also threaten human health (Salehi et al., 2017). Therefore, the use of organic farming systems can be an option for the production of foods with high nutritional quality without causing harm to the environment. In addition, due to the numerous benefits, the use of organic fertilizers is essential to improve soil quality and consequently crop yield (Bajeli et al., 2016). Soil nutrient management is an important practice to achieve high yields (Rostaei et al. 2015). In addition, organic fertilizer applications can be a valuable resource for replenishing the organic matter content in most soils (Reddy et al., 2000; Salehi et al., 2018). Food and nutrition security are some of the main global concerns, therefore, it is necessary to shift attention from staple crops to non-basic crops on a global scale to meet the growing demand for food (Kumari and Chaudhary, 2020).

Materials and Methods

Study area and experimental design

In the study, two experiments in the south of Brazil were conducted with buckwheat in 2017 and 2018. The soil of the experimental areas is classified as Typical Dystroferric Red Latosol (Oxisol) and the climate of the region, according to the Köppen classification, of the Cfa type, with hot summer without dry season (Alvares et al., 2013). Ten days before sowing, soil analysis was performed at the different study sites and chemical characteristics were identified in Augusto Pestana (pH = 6,5; P = 34,4 mg dm^{-3}; K = 262 mg dm^{-3}; OM = 3,5%; Al = 0 $cmol_c$ dm^{-3}; Ca = 6,6 $cmol_c$ dm^{-3} and Mg = 3,4 $cmol_c$ dm^{-3}) and Três de Maio (pH = 6,2; P = 33,9 mg dm^{-3}; K =200 mg dm^{-3} OM = 3,4%; Al= 0 $cmol_c$ dm^{-3}; Ca = 6,5 $cmol_c$ dm^{-3} and Mg = 2,5 $cmol_c$ dm^{-3}).

Experiment one was carried out in a randomized block design with eight replications in a 4 x 2 factorial, for sowing density (40, 80, 120 and 160 kg ha^{-1}) and growing location Augusto Pestana, RS (28° 26 '30'' S latitude and 54° 00' 58'' W longitude) and Três de Maio, RS (27° 45' 9" S latitude and 54°14'37'' W longitude), respectively. Prior to sowing, the seeds were sent to the laboratory for analysis of germination and vigor for density correction, seeking to reach 100% germination. Before sowing, in both places, weed control was carried out with application of metsulfuron-methyl herbicide at a dose of 4 g ha^{-1}, for drying the biomass and direct seeding on straw, without soil disturbance. In different years and places, sowing was carried out in the first half of December with a seeder-fertilizer to compose the plot consisting of 5 lines of 5 m in length and spacing between lines of 0.20 m, forming the experimental unit of 5 m^2. At sowing, 5 kg ha^{-1} of N and 45 and 30 kg ha^{-1} of P_2O_5 and K_2O, respectively, were applied in the NPK 5-20-20 fertilizer formulation. During the execution of the study, fungicide and insecticide applications were not carried out due to the absence of symptoms of attack by diseases and insects during cultivation.

Experiment two was carried out in a randomized block design with eight replications in a 2 x 2 factorial, for sowing time (September and December) and growing system (conventional and organic), respectively, carried out in Augusto Pestana, RS. The geographic location and chemical characteristics of the soil in the experimental area have been described previously. Before sowing, the seeds were sent to the laboratory for analysis of germination and vigor for correction in 100% germination of the sowing density in 100 kg ha^{-1}. In both growing systems, sowing was carried out with a seeder-fertilizer for the composition of the plot consisting of 5 rows of 15 m in length and spacing between rows of 0.20 m, forming the experimental unit of 15 m².

In the conventional cropping system, sowing is carried out directly on straw without soil disturbance and involves the use of herbicides and fertilizers. Therefore, weed control was carried out with metsulfuron-methyl herbicide at a dose of 4 g ha^{-1}. At sowing, 5 kg ha^{-1} of N and 45 and 30 kg ha^{-1} of P_2O_5 and K_2O, respectively, were applied in the NPK 5-20-20 fertilizer formulation. In addition, in topdressing, 35 kg ha^{-1} of nitrogen was applied with the urea source applied around 25 to 30 days after plant emergence. In the organic growing system, prior to sowing, the control of weeds was carried out by turning over the soil with the use of harrowing and no fungicide, insecticide, herbicide and fertilizers during the cultivation cycle.

Variables analyzed

In the different experiments, in the experimental field, days from emergence to flowering (DEF, days), days from flowering to maturity (DFM, days), days from emergence to maturity (DEM, days), and plant height (PH, cm) were measured. Grain yield was obtained by cutting three central lines of each plot at the stage of harvest maturity, with grain moisture around 22%. The plants were threshed with a stationary harvester and sent to the laboratory for correction of grain moisture to 13% and weighing to estimate grain yield (GY, kg ha^{-1}). The thousand grain mass (TGM, g) was determined by counting 250 grains and weighing in a precision scale, later multiplied by four. The hectoliter mass (HM, kg hl^{-1}) was obtained by the grain mass from a cube of known volume of 250 cm³, and converted to kg hl^{-1}.

Means and regression statistical analysis

When meeting the assumptions of homogeneity and normality via Bartlet and Liliefors tests ($p<0.05$), an analysis of variance was performed to detect the main and interaction effects. After that, in experiment 1, analysis of variance, means and the adjustment of regression were carried out to estimate the optimal density with expression of grain yield. Under conditions where there was significant quadratic behavior $(GY = b_0 \pm b_1 x \pm b_2 x^2)$ the optimal seeding density (OD) was obtained by the equation $\left(OD = -\frac{b_1}{2b_2}\right)$ with estimation of grain yield. Equations that describe the behavior of the other agronomic indicators and respective simulation were obtained, considering the optimum density obtained for grain yield. In experiment 2, as it represents a factorial with treatments with a qualitative effect, multiple comparisons of means were performed using the Scott Knott test ($p < 0.05$) to analyze sowing times and growing systems in different crop seasons. For all these analyses, the Genes computer program was used (Cruz, 2006).

Conclusion

The sowing density around 110 kg ha^{-1} brings benefits in the growing of buckwheat in reaching maximum grain yield in conventional and organic systems. Sowing in September and December is possible regardless of the growing system, however, grain yield is maximized under the milder temperature conditions of September. The grain yield in an organic system, although statistically inferior to the conventional one, proves to be advantageous due to the reduced variation in yield allied to the added value of the product without the use of pesticides and fertilizers.

Acknowledgments

The authors would like to thank CNPq, FAPERGS, CAPES, and UNIJUÍ and Setrem for the contribution of resources destined to the development of this study and for the scholarships for Scientific and Technological Initiation, Technical Support, Graduate Studies and Research Productivity.

References

Alvares CA, Stape JL, Sentelhas PC, Goncçalves, JM, Sparovek, G (2013) Köppen's climate classification map for Brazil. Meteorol Z. 22(6): 711-728.

Arenhardt EG, Silva JAG, Gewehr E, Oliveira AC, Binelo MO, Valdiero AC, Gzergorczick ME, Lima ARC (2015) The nitrogen supply in wheat cultivation dependent on weather conditions and succession system in southern Brazil. Afr J Agric Res. 10: 4322-4330.

Arduini I, Masoni A, Mariotti M (2016) A growth scale for the phasic development of common buckwheat. Acta Agric Scand B Soil Plant Sci. 66(3): 215-228.

Bajeli J, Tripathia S, Kumar A, Tripathi A, Upadhyayba RK (2016) Organic manures a convincing source for quality production of Japanese mint (*Mentha arvensis L.*). Ind Crop Prod. 83: 603-606.

Carvalho RM, Szlafsztein CF (2019) Urban vegetation loss and ecosystem services: The influence on climate regulation and noise and air pollution. Environ Pollut. 245: 844-852.

Castro GSA, Costa CHM, Neto JF (2012) Ecofisiologia da aveia branca. Sci Agrar Parana. 11: 1–15.

Campbell CG (1997) Buckwheat (Fagopyrum Esculentum Moench.) Promoting the Conservation and Use of Underutilized and Neglected Crops. Rome 19. Int Plant Gentic Resour Inst. 95 p.

Cruz CD (2006) Programa GENES: Estatística experimental e matrizes. Viçosa: Ed. UFV.

Domingos IFN, Bilsborrow PE (2021) The effect of variety and sowing date on the growth, development, yield and quality of common buckwheat (Fagopyrum esculentum Moench). Eur J Agron. 126: 126264.

Estrada MA, Almeida ÂA, Vargas AB, Almeida FS (2019) Diversidade, riqueza e abundância da mirmecofauna em áreas sob cultivo orgânico e convencional. Acta Biol Catarin. 6(2): 87-103.

Fang X, Li Y, Nie J, Wang C, Huang K, Zhang Y, Yuan X (2018) Effects of nitrogen fertilizer and planting density on photosynthetic characteristics of leaves, agronomic characteristics and grain yield in common buckwheat *(Fagopyrum esculentum M*). Field Crop Res. 219: 160-168.

Ferreira AS, Coelho AB (2017) O papel dos preços e do dispêndio no consumo de alimentos orgânicos e convencionais no Brasil. Rev Econ Soc Rur. 55(4): 625-640.

Fleck NG, Schaedler CE, Agostinetto D, Rigoli RP, Dal Magro T, Tironi SP (2009) Associação de características de planta em cultivares de aveia com habilidade competitiva. Planta Daninha. 27(2): 211-220.

Furlan AC, Santolin MLR, Scapinello C, Moreira I, Faria HG (2006) Avaliação nutricional do trigo mourisco (Fagopyrum esculentum, Moench) para coelhos em crescimento. Acta Sci Anim Sci. 28(1): 22-27.

Gavrić T, Gadzo D, Đikić M, Ašimović Z (2017) Effects of sowing rate on yield and total phenolic contents of common buckwheat. Radovi Poljoprivrednog Fakulteta Univerziteta u Sarajevu/Works of the Faculty of Agriculture University of Sarajevo. 67(2): 17-24.

Gavrić T, Čadro S, Gadžo D, Đikić M, Bezdrib M, Jovović Z, Jurković J, Hamidović S (2018) Influence of meteorological parameters on the yield and Chemical composition of common buckwheat (Fagopyrum esculentum Moench). Agric For. 64(4): 113-120.

Ge RH, Wang H (2020) Nutrient components and bioactive compounds in tartary buckwheat bran and flour as affected by thermal processing. Int J Food Prop 23(1): 127-137.

Gonçalves FMF, Debiage RR, Silva RMGP, Petrônio P (2016) Fagopyrum esculentum Moench: A crop with many purposes in agriculture and human nutrition. Afr J Agric Res. 11(12): 983-989.

Guarienti EM, Ciacco CF, Rocca G, Jesus L De, Del A, Maria C, Camargo DO (2004) Influência das temperaturas mínima e máxima em características de qualidade industrial e em rendimento de grãos de trigo. Food Sci Technol. 24(4): 505-515.

Inamullah GS, Muhammad A, Asad AK, Shazma A, Shah AK (2012) Response of common buckwheat to nitrogen and phophorus fertilization. Sarhad J Agric. 28(2): 171-178.

Joshi DC, Chaudhari GV, Sood S, Kant L, Pattanayak A, Zhang K, Fan Y, Janovská, D, Meglič V, Zhou M (2019) Revisiting the versatile buckwheat: reinvigorating genetic gains through integrated breeding and genomics approach. Planta, 250(3): 783-801.

Juszczak D, Wesolowski M (2011) Phenological phases of buckwheat (Fagopyrum esculentum Mnch.) in the primary and secondary crop depending on seeding rate. Acta Agrobot. 64(4): 213-225.

Jung KGH, Kim SL, Kim MJ, Kim SK, Park JH, Kim CG, Heu S (2015) Effect of Sowing Time on Buckwheat (Fagopyrum esculentum Moench) Growth and Yield in Central. J Crop Sci Biotechnol.18(4): 285-291.

Kalinova J, Moudry J, Curn, V (2005) Yield formation in common buckwheat (Fagopyrum esculentum Moench). Acta Agron Hung. 53(3): 283-291.

Klein VA, Navarini LL, Baseggio M, Madalosso T, Costa LO (2010) Trigo mourisco: uma planta de triplo propósito e uma opção para rotação de culturas em áreas sob plantio direto. Rev Plant Dir. 117.

Kumari A, Chaudhary HK (2020) Nutraceutical crop buckwheat: a concealed wealth in the lap of Himalayas. Crit Rev Biotechnol. 40(4): 539-554.

Lamego FP, Ruchel Q, Kaspary TE, Gallon M, Basso CJ, Santi AL (2013) Habilidade competitiva de cultivares de trigo com plantas daninhas. Planta Daninha, 31(3): 521-531.

Link L, Oligini KF, Batista VV, Adami PF (2019) Conservação do agroecossistema com manejo agrícola intensivo. Appl Res Agrotech. 12 (3): 119-126.

Lopez LD, Pinto EP, Borger BR, Kaipers KFC, Lucchetta L, Tonial IB (2017) Interferência do sistema de cultivo, radiação UV-C e método de secagem na qualidade da farinha de subprodutos de uva. Científica. 45(4): 347-354.

Mantai RD, Silva JAG, Sausen ATZR, Costa JS, Fernandes SB, Ubessi C (2015) A eficiência na produção de biomassa e grãos de aveia pelo uso do nitrogênio. Rev Bras Eng Agr Amb. 19(4): 343-349.

Marolli A, Silva JAG da, Romitti MV, Mantai RD, Scremin OB, Frantz RZ, Sawicki, S, Gzergorczick ME, De Lima ARC (2017) Contributive effect of growth regulator Trinexapac-Ethyl to oats yield in Brazil. Afr J Agric Res. 12(10): 795-804.

Nam TG, Kim D, Eom SH (2018) Effects of light sources on major flavonoids and antioxidant activity in common buckwheat sprouts. Food Sci Biotechnol. 27(1): 169-176.

Nunes J, Peres DM, Souza GBP, Canzi GM, Effting PB, Resende JD, Moreira CR (2019) Monitoramento de pragas no desenvolvimento inicial da cultura do trigo mourisco na região oeste do Paraná. Rev Tec Cient. 17: 1-11.

Pereira AP, Schoffel A, Koefender J, Camera JN, Golle DP, Horn, RC (2017) Ciclagem de nutrientes por plantas de cobertura de verão. Rev Cienc Agra. 40(4): 799-807.

Pintado T, Herrero AM, Jiménez-Colmenero F, Ruizcapillas C (2016) Strategies for incorporationof chia (*Salvia hispânica* L.) in frankfurters as a health-promoting ingrediente. Meat Sci. 114: 75-84.

Popović V, Sikora V, Glamočlija Đ, Ikanović J, Filipović V, Tabaković M, Simić D (2013) Influence of agro-ecological conditions and foliar fertilization on yield and yield componentes of buckwheat in conventional and organic cropping system. Biotechnol Anim Husb. 29(3): 537-546.

Reddy DD, Rao AS, Rupa TR (2000) Effects of continuous use of cattle manure and fertilizer phosphorus on crop yield and soil organic phosphorus in a Vertisol. Bioresource Technol. 75(2): 113-118.

Rosell CM (2013) Alimentos sin gluten derivados de cereales. In: L Rodrigo, AS Peña (ed) Enfermedad celíaca y sensibilidad al gluten no celíaca, Barcelona: OmniaScience. 447-461.

Rostaei H, Fallah S, Abbasi SA (2015) Effect of fertilizer sources on the growth, yield and yield components of fenugreek intercropped with black cumin. Electron J Prod. 7(4): 197-222.

Salehi A, Fallah S, Kaul HP (2017) Effects of litter and inorganic fertilizers on the yield and yield of buckwheat and fenugreek seeds in inter-row intercropping. Arch Agron Soil Sci. 63(8): 1121-1136.

Salehi A, Mehdi B, Fallah S, Kaul HP, Neugschwandtner RW (2018) Productivity and nutrient use efficiency with integrated fertilization of buckwheat–fenugreek intercrops. Nutr Cycl Agroecosys. 110(3): 407-425.

Siracusa, L, Gresta, F, Sperlinga E, Ruberto G (2017) Effect of sowing time and soil water content on grain yield and phenolic profile of four varieties of buckwheat (*Fagopyrum esculentum* Moench.) in a Mediterranean environment. J Food Compos Anal. 62: 1-7.

Sobhani MR, Rahmikhdoev G, Mazaheri D, Majidian M (2012) Effects of sowing date, cropping pattern and nitrogen on CGR, yield and yield component summer sowing buckwheat (Fagopyrum esculentum Moench). J Appl Environ Biol Sci. 2 (1): 35-46.

Storck L, Cargnelutti Filho A, Guadagnin JP (2014) Análise conjunta de ensaios de cultivares de milho por classes de interação genótipo x ambiente. Pesqui Agropecu Bras. 49(3): 163-172.

Teixeira MB, Loss A, Pereira MG, Pimentel C (2012) Decomposição e ciclagem de nutrientes dos resíduos de quatro plantas de cobertura do solo. Idesia (Arica). 30(1): 55-64.

Tricase C, Lamonaca E, Ingrao C, Bacenetti J, Giudice AL (2018) A comparative Life Cycle Assessment between organic and conventional barley cultivation for sustainable agriculture pathways. J Clean Prod. 172: 3747-3759.

Zhu F (2016) Buckwheat starch: Structures, properties, and applications. Trends Food Sci Tech. 49: 121-135.