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CROP PRODUCTION

Buckwheat, alternative as second crop during the Summer and the Autumn in Southern Brazil: a crop review

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ABSTRACT: Buckwheat is known for its aptitude as green manure, as it increases soil's physical and chemical properties at the same time it has none or very few fertilization requirements besides a fast canopy closure and has no ravagers or natural enemies documented in Brazil. This crop has the potential to fill an empty period known as the "Autumn gap" in Southern Brazil, which is characterized by the low or no forage offer at all, justified by the fact its forage has the same quality as that of a grass forage, besides, its grains, highly nutritious, can also be consumed by humans, ruminants, or non-ruminants. This review aims to provide relevant information about recent buckwheat research to make it a viable alternative for the Autumn gap.
Key words: Buckwheat, Autumn Gap, green manure, Autumn crop, *Fagopyrum esculentum* Moench.

Trigo Mourisco, alternativa como segunda cultura de verão e para o outono no Sul do Brasil: uma revisão da cultura

RESUMO: O trigo mourisco é conhecido por sua aptidão como adubo verde, melhorando as propriedades físicas e químicas do solo ao mesmo tempo que possui nenhuma ou baixíssimas requisições de fertilização, além de rápido fechamento de dossel e de não possuir pragas nem outros inimigos naturais documentados no Brasil. Essa cultura tem o potencial de cultivo para preencher o período de tempo conhecido como "vazio outonal" no Sul do Brasil, período caracterizado pela baixa ou nenhuma oferta de forragem. O valor nutritivo é bom, além de seus grãos, altamente nutritivos, também poderem ser consumidos por humanos, ruminantes e não-ruminantes. Essa revisão visa fornecer informações relevantes da pesquisa sobre o trigo mourisco nos últimos anos objetivando o incentivo a viabilização dessa cultura como alternativa no vazio outonal no sul do Brasil.
Palavras-chave: trigo mourisco, vazio outonal, adubo verde, cultivo de outono, *Fagopyrum esculentum* Moench.

INTRODUCTION

Buckwheat (in portuguese known as "trigo mourisco", "trigo sarraceno" or "tatarca", *Fagopyrum esculentum* Moench), is a pseudocereal plant belonging to the Polygonaceae family (SILVA et al., 2021). This crop has its origins in Asia, though it is also grown in Europe, the United States and Canada (TOHGI et al., 2011).

The plants have a height varying from 0.6 to 1.5 m, they're annuals and of indeterminate growth. The stems are hollow, and their color varies from green to red. The root, pivotant, is not vigourous but is strongly branched (SMALL, 2017). In the inflorescences, the raceme has flowers whose color is frequently white (Figure 1), nonetheless pink and, occasionally, yellow flowers are also observed and the flower maturation is not uniform (SMALL, 2017; CHRUNGOO & CHETTRY, 2021). The fruits are achenes (commonly called "grains"), they have the dimension from 5-8 mm in length and are frequently black, brown or even grayish and silverish, with a triangular shape when cut transversally (SMALL, 2017).

Buckwheat has grains that can be consumed by humans as well as animals, and are ideal for people with celiac disease for products made from their flour does not contain gluten (GONÇALVES et al., 2016). Besides, the crop can be also used as green manure for it improves physical and chemical soil attributes and fits very well in organic production system due to its weed-suppressing ability (ADAMI et al., 2020) and the capacity to attract diverse insects that predate

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Figure 1 - Buckwheat, sown on early January/2023, with white flowers at Dois Vizinhos, Paraná State, Brazil, April/2023.

on other crops' ravagers (GONÇALVES et al., 2016, BORTOLOTTO et al., 2022).

Russia, China, Ukraine and the United States are the leader (Figure 2) buckwheat producers in the world (FAOSTAT, 2021). Even if buckwheat grown surface has decreased in the last 30 years (Figure 3), the cultivated global area in 2013 was superior to 2400000 ha, 48000 out of which were in Brazil, in 2020 the total crop area was 1850000 ha, 46400 out of which were in Brazil (FAOSTAT, 2021), mostly located in the Southern regions.

Some crop growers have been using buckwheat in integrated crop-livestock systems as a succession to soybean, filling in the gap known as the "Autumn gap", when, typically, there's a lack on forage offer (ADAMI et al., 2020). This deficit period occurs when perennial pastures or annual Summer forages are in the end of their lifecycles (with a low support and quality) and the Winter forages are still not ready to receive the cattle. In these months, when Autumn takes place and the Winter starts, buckwheat can be fit in the system and offer good quality forage for animals, diminishing production costs by allowing less preserved pastures to be required. In Southwestern Paraná State, for example, the Gap Period starts in February and lasts until the end of April (ADAMI et al., 2020).

Crop rotation including buckwheat can be profitable (VOLSI et al., 2020), given the mentioned characteristics, provided that it is managed in the right way. Buckwheat is an excellent choice as a Summer second crop, especially in Southern Brazilian conditions. Therefore, this review aims providing information that reinforce buckwheat as an alternative during the Autumn gap in Southern Brazil. based on recent research.

DEVELOPMENT

Agronomic traits

Seeds and sowing

The recommended tests to evaluate seed lot vigour are the germination under low temperatures and the emergence speed index (PONCE et al., 2019a). Germination percentage and seed vigour are directly related to seed size, the bigger a buckwheat seed is, the higher its vigour and germination rate tends to be, regardless of cultivar (PONCE et al., 2019b). The recommended sowing density found in the literature varies significantly, from 60 until 100 kg ha^{-1} (JUSZCZAK & WESOŁOWSKI, 2011), resulting in 250 to 430 plants m^{-2}, and from 40 kg ha^{-1}, with big seeds, to 55 kg ha^{-1} with smaller seeds, aiming 70 plants m^{-2} (MÜTZENBERG et al., 2022).

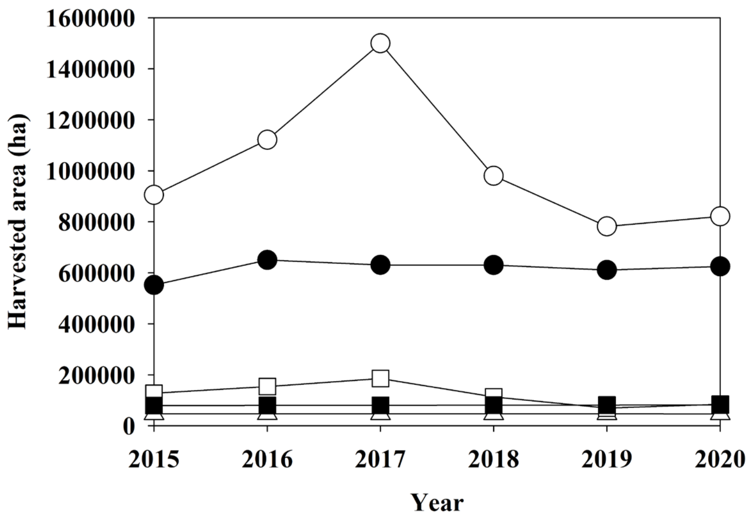

Figure 2 - Buckwheat harvested area (ha), from 2015 to 2020, in Brazil (Δ), China (●), the Russian Federation (○), Ukraine (□) and the United States (■) (FAOSTAT, 2021).

The thousand-seed weight ranged from 19 to 28 g (FANG et al., 2018a), from 31 to 33 g (LINK et al., 2020), around 24 g (VERMA et al., 2020), from 29 to 34 g (MÜTZENBERG et al., 2022); and from 26 to 29 g (DA ROSA et al., 2022), depending on the cultivar the sieve on which the seeds have passed through. Emergence happens generally from 5 to 6 days after sowing. The optimal germination temperature is 10 °C (KALINOVA & MOUDRY, 2003), but the plants can germinate in the range from 5 to 42 °C (JUSZCZAK & WESOŁOWSKI, 2011).

Sowing is recommended to be done as soon as soybean is harvested and the plant cycle will last about 70 days or 90 days under colder conditions (CHRUNGOO & CHETTRY, 2021). Though the crop can be sown later in the year, this is not recommended due to the risk of frost in Southern Brazil, especially from late May to July (WREGE et al., 2018) as buckwheat is susceptible to frost especially in the early stages of development (KALINOVA & MOUDRY, 2003).

Nitrogen requirements, yield and growth

Though it is known for not having high fertility requirements, the use of fertilizers, whether chemical or not, may increase the yield (SALEHI et al., 2018). GUGLIELMINI et al. (2019) obtained yields up to 4100 kg ha^{-1} using 70 kg N ha^{-1} in the form of urea (46% N) on the sowing period. Other reported yields, in kg ha^{-1}, without and with N fertilizers, in the literature are very discrepant, like 1215 and 3000 (POPOVIC et al., 2013), from 890 to 5240 (KASAJIMA et al., 2017) and 1830 (WANG et al., 2020).

When studying the effects of nitrogen fertilization (0; 45 and 90 kg N ha^{-1}) and plant density (60; 90 and 120 plant m^{-2}, inter-row spacing of 33 cm) on the buckwheat yield components, FANG et al. (2018a) found a positive effect with a nitrogen fertilization level of 45 kg N ha^{-1} and plant density of 90 individuals m^{-2}. According to these researchers, yield increased from 1160 to 1340 kg ha^{-1} when the nitrogen fertilization increased from 0 to 45 kg N ha^{-1}, on the average of the 3 plant densities. Yield increases were justified by an increase in the leaf area index and the net photosynthetic rate.

The critical yield-defining period in buckwheat, as described by GUGLIELMINI et al. (2019), is from when the flower buds start to open until when the first achenes begin to form. Increasing plant density, per square meter, may decrease the light interception and the net photosynthetic rate per plant, resulting in the reduction of formed achenes per raceme, but not their individual weight, which demonstrates that yield is related to the number of achenes but not the thousand-seed weight (ROTILI et al., 2023). This phase represents about 45% of all the species lifecycle, which, in thermal time (or heat accumulation units), is around 1200, considering a base temperature of 5 °C (AHMED et al., 2014) and a limit of 25 °C (ARDUINI et al., 2016).

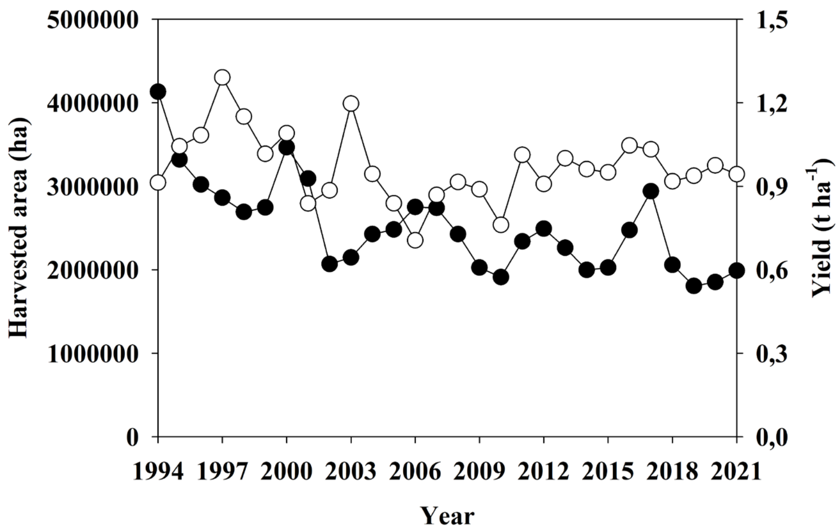

Figure 3 - Global buckwheat harvested area (ha) (●) and yield (t ha^{-1}) (○) from 1994 to 2021 (FAOSTAT, 2021).

A growth scale was set for buckwheat (Table 1) (ARDUINI et al., 2016), based on the previously mentioned temperatures. According to these authors, this scale associates numbers to respective phoenological stages, for example, germination takes place at stage 09, flower buds appear at stage 62, and the first fruits appear at stage 70. According to its indicators, the best time to harvest is at stage 88, when all achenes have a dark brown color, or have already been aborted.

Straw decomposition and nutrient cycling

The relationship C/N found by MENEZES & LEANDRO (2004) was 22,59, very close to 21, which characterizes a fast-decomposing rate (COSTA et al., 2015). According to these same authors, buckwheat has a higher nutrient cycling rate than other cover crops evaluated by the authors, such as: jack bean (*Canavalia ensiformis*), *Stizolobium dierrigianum*, *Stizolobium murens*, Pearl Millet (*Pennicetum typhoides*), Sun Hemp (*Crotalaria juncea* L.), Black Oats (*Avena strigosa*) and ruzigrass (*Brachiaria ruziziensis*).

Irrigation and waterdeficit

Though for a nitrogen deficit the plant does not show a reduction on the thousand seed weight but for a number of achenes, a water deficit can reduce both (MARIOTTI et al., 2016). Average water deficits before flowering do not have an influence on the grain yield, whichever phoenological stage they take place (MARIOTTI et al., 2016), additionally, irrigation on buckwheat increases insignificantly the yield, unless the water deficit is very high. These same authors demonstrate that only after flowering irrigation may have some effect. Nonetheless, water deficits can impact total aerial biomass at the time it is harvested (GERM & GABERSCIK, 2016), which is a factor to be taken into account when considering buckwheat as animal fodder.

Interactions with soil microfauna and phosphorus

Buckwheat has a positive interaction with soil microorganisms in a crop rotation system (KARPENKO et al., 2020). If grown in monoculture for successive years, nonetheless, it will result in the already known soil available nutrient impoverishment as well as a decrease in the organic matter content and a reduction in the diversity and biomass of the microbiota (WANG et al., 2020), which are factors highly influencing soil fertility.

Soil microorganisms, and their interactions with the plant, are essential for phosphorus cycling (HALLAMA et al., 2019). For buckwheat, the symbiotic relationships with mycorrhizae arbuscular fungi auxiliate increasing phosphorus availability for the plant (BOGLAIENKO et al., 2014). In the study conducted by these same authors, it was demonstrated that, in soil where mycorrhizae spores are present, buckwheat will spread its roots.

Buckwheat's ability to turn soil phosphorus available to following crops is influenced and limited

Table 1 - Simplified buckwheat growth scale, resumed from ARDUINI et al. (2016).

Code	--------------------------Growth Stage--------------------------	---------------------------Description---------------------------
00	Dry seed	Sowing date
09	Emergence	Cotyledons emerge from soil
10	Cotyledon	Cotyledons unfolded
11	First leaf	First leaf unfolded
62	Beginning of flowering	Terminal inflorescence flowers
70	First green fruits	Green achenes visible
88	End of fruit ripening	Achenes mature or aborted
90	Beginning of plant senescence	Withering starts
97	Plant dead	Stem turns brown and dries up

by the place where it is grown (RICK et al., 2011) and its environmental abiotic variables, nonetheless, it was demonstrated that even under phosphorus restriction, the buckwheat plant spreads well its roots in the soil (ZHU et al., 2002), for it has adaptative mechanisms to low-P availability. This adaptative ability is linked to the symbiotic relationship with fungi, that results in a high phosphatase activity per root unit area and soil acidification (POSSINGER et al., 2013), root exudation of organic acids and phenolic compounds, and subsequent increase in the phosphorus availability (AMANN & AMBERGER, 1989; TALBOYS et al., 2016).

Soil pH reduction to make P available is directly linked to hydrogen cations, and in a minor scale to the liberation of organic acids (KREUZEDER et al., 2018; LOPES et al., 2021). As demonstrated by TEBOH & FRANZEN (2011), the largest part of the phosphorus solubilized by buckwheat is from the labile fraction of the soil, which can provide an increase in the available phosphorus for the succeeding crops. Additionally, as demonstraded by LOPES et al. (2021), buckwheat roots can make available phosphorus from low-solubility sources, such as certain kinds of rocks, allowing this phosphorus to be potentially available to succeeding crops.

Limitations

The main limitation for this crop is lodging (FURLAN et al., 2006; MORISHITA et al., 2020). Increasing plant population is one of the factors that increases lodging (MÜTZENBERG et al., 2022). Given that lignin is a compound that, in the stems, prevents lodging (with its levels varying for each species), WANG et al. (2015) studied applying uniconazole on the leaves or as a seedcoat, aiming increasing the lignin content, and obtained results that indicated a reduction in buckwheat lodging after uniconazole was applied. Similar results were obtaining, applying uniconazole, by FANG et al. (2018b). It is worthy of notice that, an excessive amount of nitrogen and increase in the sowing density are related to a lower lignin content and higher lodging risk in buckwheat (WANG et al., 2015).

LINK et al. (2021) also described that it is difficult for buckwheat to be chemically controlled due to the reseeding effect, which may be a problem for the subsequent crop (generally wheat in Southern Brazil) and may be act as a limiting factor for buckwheat as the chosen cover crop. Mixes of the herbicides bromoxynil + MCPA ester and fluroxypyr + bromoxynil were able to control voluntary buckwheat in wheat in experiments conducted in the United States (LYON et al, 2019), but such studies are still necessary in Brazil to provide a legal basis for such applications.

Other agronomic advantages

Buckwheat also has as characteristic having evolved in acidic acids, where the pH is as low as 5 and with a high aluminum content and manages to grow under those conditions (MA et al., 1997). Buckwheat even absorbs aluminum in the form of Al^{3+} and accumulates it in the leaves (MA & HIRADATE, 2000), but not in the seeds (SHEN et al., 2006). When in contact with the Al^{3+} cations, oxalate is produced, both as exudate as well as an internal compound, and forms then the Al-oxalate non-toxic form (ZHENG et al., 1998). When it is translocated from the roots to the leaves, Al-oxalate is converted to Al-citrate in the xylem and reconverted to the stable Al-oxalate in the leaves (MA & HIRADATE, 2000), which is stocked in this form or sequestered by cell vacuoles (SHEN et al., 2002). Another advantage of buckwheat as a soil cover is preventing erosion and run-off. BARBOSA et al. (2022) demonstrated water and soil retaining properties on the buckwheat crop growth area, just after the crop was sown, for in two weeks the canopy was already closed. Such properties were also demonstrated by PODLESNYH et al. (2021), when using buckwheat in a crop rotation with wheat and barley. FANG et al. (2017), in a two-year study in a mountainous region in China, proved that buckwheat is a crop that prevents run-off and extreme hydrological events more than mung beans and sesame, but less than arboreous species.

Weed control and allelopathy

Cover crops control and suppress weed due to intense competition for resources such as water, light, physical room and nutrients. It has been demonstrated that buckwheat has a high suppressing ability in a short (GHAHREMANI et al., 2021) and long term (SMITH et al., 2020), mono and dicotyledons, with a special mention to a lower amount of dicotyledons than those controlled by cover crops such as oats. This makes buckwheat a desirable crop in organics, provided that one of the greatest barriers to be overcome for the expansion of organics is precisely the amount of weed. As a matter of fact, buckwheat is already grown in some regions, such as North Dakota, in the United States, in organic crop systems to suppress weed (TEBOH & FRANZEN, 2011).

In a study performed in the Australian State of New South Wales, SHABBIR et al. (2022) demonstrated that, for two different types of soil, under the same climatic influence, when comparing with fallow plots, buckwheat plots had a weed biomass 65 and 94 % lower, for a clayish and sandy soil, respectively.

Quantified biomass reductions, when buckwheat was used to suppress weed, were, respectively, 68; 68; 87 and 90% for *E. crus-galli*, *Portulaca oleracea*, *C. album* and *Amaranthus lividus* (SANGEETHA & BASKAR, 2015). The same authors found that placing buckwheat pellets on the soil, in the order of 2 t ha^{-1}, was able to suppress completely the species *C. difformis* and *Donapatrium junceum*, besides considerably reducing the growth of *E. crus-galli*, *E.articularis* and *M. vaginalis*.

Though buckwheat has desirable characteristics to compete with weed, inappropriate interrow spacing, as well as inadequate nitrogen provision, may imply on those characteristics being lost, even when buckwheat has a low nitrogen demand. KOLARIC et al. (2021) found that the ideal interrow spacing is of 25 cm, whilst an interrow spacing of 50 cm implied in a yield reduction and higher weed population, especially *Circium sp*. and absinth (*Ambrosia artemisiifolia* L.).

It has been also demonstrated that, when soybean rows are sown with buckwheat rows between them, the amount of weed is reduced in, approximately 50% compared to soybean monoculture, and an increase in soybean fatty acids was observed as well (BISZCZAK et al., 2020). Buckwheat, when sown along with soybean, reduces weed dry matter more than lentils, sorghum and sunflower (CHERIERE et al., 2020), which is associated to its fast development rate, that means a high competitivity for light (BICKSLER & MASIUNAS, 2009).

Buckwheat can be used as a sole crop or as a mix of cultures (SMALL, 2017), being efficient in suppressing weed at both cases (WORTMAN et al., 2012). Mixes can be done with white mustard (MASILIONYTE et al., 2017), phacelia, sunflower, cowpea, hairy vetch (MALLINGER et al., 2019), barley, chickling pea (GHAHREMANI et al., 2021) and maize (LOPES et al., 2021). Nonetheless, the weed suppression ability is higher when used as a sole crop, for not having to compete with one extra species on the field, reaching a weed biomass reduction up to 98% (HOLMES et al., 2017; SMITH et al., 2020). Additionally, the effects of buckwheat mixes on the yield on subsequent crops are still scarce (SILVA et al., 2021).

The ability buckwheat has to compete with weeds suggests that farmers will not face major problems when harvesting for grain, for weed biomass shall be low when the harvest time comes.

Buckwheat also has allelopathic properties in its seeds (SZWED et al., 2019) and roots (KALINOVA et al., 2007). The triggering mechanism for allelopathy is through root recognition amongst the different species which occurs through root exudates and modifying those same root exudates in an environment with interspecific competition (GFELLER et al., 2018). The main allelopathic compound is the flavonoid rutin, whose content varies from 4 to 6 % (CHLOPICKA et al., 2012). Vanillic acid and other compounds with similar spectrum to that of gallic and palmitic acids can also be found (KALINOVA et al., 2007). Some researchers have also found dietilftalate and catechin as compounds with allelopathic properties in buckwheat (IQBAL et al., 2002, 2003).

KALINOVA et al. (2007) affirm that rutin is not necessarily an exudate, for its origin is from dead parts decomposition, also, when buckwheat seedlings were grown in agar and not on the soil, rutin presence was not observed and it was, nonetheless, observed, when buckwheat was grown on the soil and reached higher phenological stages. Rutin may inhibit, from concentrations of 32 to 128 µg mL^{-1}, other species germination for it suppresses the accumulation of indol-acetic acid (IAA) in the hypocotyl (BASILE et al., 2000).

Interactions with insects

Buckwheat, when used as a cover crop, may affect the local insect fauna. When sown as a cover crop on irrigated vine mid-rows in southern California, the number of observed insects was 27 times higher than in vines where no buckwheat had grown, with or without irrigation (IRVIN et al., 2016), including the number of ravagers' predators. Nonetheless, the authors clarify that grape quality was lower due to damage from insects and do not recommend buckwheat on the interrows for it hosts *Xylella fastidiosa* Wells, a bacteria that causes Pierce's Disease and has as vector an insect that feeds on the raw xylem sap.

The long flowering period along with the abundant polen production attract many insects, pollinators as well as predators such as syrphids (PONTIN et al., 2006; FRÉCHETTE et al, 2008, TAKI et al., 2009). Individuals from the families Dolichopodidae, Sphecidae, Eumenidae, Vespidae, Scoliidae and Tiphiidae were witnessed predating other insects on buckwheat flowers (CAMPBELL et al., 2016; BORTOLOTTO et al., 2022).

Abundant pollen turns buckwheat into a viable crop for being used as a pollinator population maintainer in areas of intensive crop growth (CARRECK & WILLIAMS, 2002; PONTIN et al., 2006). Nectar, which is produced in the flowers, has its production ceased in the afternoon, which reduces the presence of pollinator insects in this time of the day (BUGG & ELLIS, 1990).

The bees (*A. cerana* and *A. mellifera*) are the main, most frequent and most efficient buckwheat pollinators (JACQUEMART et al., 2007; LIU et al., 2020), along with certain diptera (KIM et al., 2022). Other insects, from the orders Hymenoptera and Diptera, would also be important buckwheat pollinators, especially those from the Formicidae family (TAKI et al., 2009; NATSUME et al., 2022). KASAJIMA et al. (2017) demonstrated that, when pollinated exclusively by diptera, buckwheat still yield decent amounts of grain. According to JACQUEMART et al. (2007), each *Apis mellifera* individual is able to visit from 14 to 20 flowers per minute and pollinates buckwheat fields for around 4 to 5 hours a day. Even so, other individuals belonging to other orders, such as Coleoptera and Lepidoptera (ARYAL et al., 2016) have also been witnessed visiting flowers and taking part on the pollination process. The same authors observed that buckwheat fields close or neighbor to natural vegetation attract more visiting insects, which suggests that preserving those natural environments and sowing buckwheat close to them, aiming maximizing pollination and maintaining the insect population.

Nemathods

Buckwheat is susceptible to *Meloydogine javanica*, *Pratylenchus penetrans* and *Xiphinema Americanum* (CHIDICHIMA et al., 2021). Buckwheat straw may have nematicide effect on *M. javanica* when the following crop was soybean (ALVES et al., 2022). Buckwheat may also increase the population of benefical nemathods, such as the ones from the genus *Helicotylenchus* (RHODES et al., 2014), notably on sugarcane.

Use in human and animal food

Grains for human food

Besides being a part of honey production, buckwheat yields grain that may become glutenfree foods. Such foods may be different kinds of bread, cookies, dough, pasta and high nutritional beers (GIMÉNEZ-BASTIDA et al., 2015) that have characteristics very similar to those barley-based beers (BRASIL et al., 2020). Grains have a very high nutritional value, and are na important source of macronutrients (potassium, calcium, magnesium and sodium) and micronutrients (manganese, zinc, selenium and copper) (WEI et al., 2003). Compared to other cereals, buckwheat has a higher fiber content (GAVRIC et al., 2018).

Flour made from buckwheat grains have a balanced aminoacid content, being particularly high in arginine and lysine (CHRISTA & SORAL-ŚMIETANA, 2008), but lower in glutamic acid and proline (ZHANG et al., 2012). The flour protein content varies from 8.5 to 18.9 %, which is higher than that of rice, millet, sorghum and maize (BOBKOV, 2016). Buckwheat grain or flour drifts presente a high flavonoid content, which are benefical to health, especially quercetin and rutin (GIMÉNEZ-BASTIDA & ZIÉLINSKI, 2015). This high flavonoid content, along with another bioactive content, classes buckwheat as a "functional food", given that those compounds can prevent diseases or even fight them. Buckwheat flour has many bioactive compounds, such as catechins, anthocyanins, isoquerticins and miricetins. According to those last authors, those bioactive compounds may have antioxidant, hypotensive, anti-inflammatory and anticancer properties, as well as improve glycose's homeostasis, reducing damages from diabetes, and also, aiding fat metabolism, preventing arteries and vein clogging.

Non-Ruminants

Introducing buckwheat in the diet of swine individuals is interesting due to its high lysine content (CHRISTA & SORAL- ŚMIETANA, 2008). Its high phenol and antioxidant contentes may aid the antioxidative enhancing of pork meat (WIJNGAARD & ARENDT, 2006). Nonetheless, the literature still lacks much information on using buckwheat as swine fodder, and the available papers are old and obsolete, requiring an update (LEIBER, 2016). FURLAN et al. (2006) studied the use of buckwheat as fodder for rabbits, and affirmed that these grains may replace entirely buckwheat bran in growing rabbit rations. According to these same authors, brute protein content in the grains is around 11.5%. For laying hens, a replacement level of 30% (BENVENUTI et al., 2012) to 40 % (LEIBER, 2016), in a diet consisting of a mix of maize and soybean, compared to the control, maintained the same hen performance. It has also been observed an increase in eggshell resistance and tocoferol enzyme concentration in the yolk when the indivuduals were fed buckwheat, and for broiler chicker, replacing up to 40% of the wheat/maize with buckwheat resulted in the same performance as the control treatment (LEIBER, 2016). Nonetheless, other authors demonstrated that above 40% of buckwheat presence in the diet dry matter may reduce the conversion rate or weight gain (JACOB & CARTER, 2008). The increase in tocoferol content, when broiler chicken were fed with buckwheat, was also noted in the animals' meat, after having shown a good acceptance by those broiler chicken as well as laying hen (LEIBER, 2016).

Ruminants

Good quality forage can be yielded by buckwheat, of higher quality than that of pearl millet and of the same nutritional value as that of grasses (GÖRGEN et al., 2016; LINK et al., 2020). Buckwheat is interesting for dairy cattle, for it fits the Autumn Gap and has values, of brute protein of 14.1-17.3%, acid detergent fiber (ADF) of 32-35.3%, neutral detergent fiber of 59.8-63.0% and total digestible nutrients (TDN) of 63.2-64.8%, besides, its dry matter digestibility is 59.8-63.0%. Buckwheat as fresh forage or silage can be successfully inserted in the diet of lactating cows, maintaining milk yield (AMELCHANKA et al., 2010; KÄLBER et al., 2011). According to CUI et al. (2015), the rutin present in buckwheat can increase the diet digestibility and milk yield, nonetheless, more studies are needed on this subject.

According to the maturity scale set by ARDUINI et al. (2016), the ideal stage to use buckwheat as forage is when the first unripe fruits appear, or during their ripening, represented in the scale from the numbers 60 to 70. This phoenological stage coincides with the highest rutin yield by the plant.

The rutin the buckwheat forage has can be used as a functional food in the diet (MARIOTTI et al., 2017), for this compound increases milk yield in bovines and increase ration digestibility (CUI et al., 2015). Rutin content is variable according to each part of the plant, and that is of 0.2 to 0.4 g kg^{-1} of dry matter (DM) in the achenes, of 50 to 80 g kg^{-1} DM in the flowers, of 30 to 70 g kg^{-1} DM in the leaves and of 7 to 12 g kg^{-1} DM in the stems (KALINOVA & DADAKOVA, 2013), the contents varying inside the mentioned range according to the plant phoenological stage (MARIOTTI et al., 2015). When ensiled, the rutin contente falls 84 up to 99 % compared to the content in the fresh forage due to its transformation in quercetin by microorganisms activity (MARIOTTI et al., 2017).

Restrictions

Buckwheat has in its composition a complex polyphenol named fagopyrin (AHMED et al., 2014). After the animal ingests the vegetable material and digests it, fagopyrin, when excessive, enters the circulatory system and may reach the skin causing fagopyrism (HINNEBURG & NEUBERT, 2004; BENKOVIČ et al., 2014) and primary photosensitization, which results in cutaneous eruptions in animals with a lighter skin. Fagopyrin concentration on buckwheat is extremely low (LI & ZHANG, 2001). Low concentrations are also found in stems and roots, but in the leaves and flowers their content is higher (EGUCHI et al., 2009; KIM & HWANG, 2020), from 5 to 15 times higher than in the stems.

CONCLUSION

Buckwheat shows itself as an interesting option as soil cover. Due to the high competitiveness with weed, absence of ravagers and diseases, interaction with pollinators and other insects, low requirements on fertility and a tolerance to a moderate hydric deficit before flowering, the crop is highly viable for organic and conventional cropping systems.

Besides that, its many purposes, like the grain production and use as animal fodder characterize it as an excellent option for the Autumn gap in Southern Brazil.

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DECLARATION OF CONFLICT OF INTERESTS

We have no conflict of interest to declare.

AUTHORS' CONTRIBUTIONS

The authors contributed equally to the manuscript.

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