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Review on weeds and weed controlling methods in soybean (*Glycine max* L.)

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Abstract
The present paper is review various research findings on weeds and weed control in soybean. Soybean is the most important oil seeds and grain legume crop in the world, in terms of total production and international trades. However, losses due to weeds have been one of the major limiting factors in soybean production. So, successful weed control is one of the most important practices for economical soybean production. Weeds that germinated at the same time as soybeans grow faster and maintain a canopy above and below the top of the soybean canopy and resulted in reduced quality. The role of weeds as alternate hosts for soybean crop pests and disease and their interference with cultivation operations resulting higher costs of production. Weeds also have effect on the use of fertilizer because they compete with the crop for nutrients. Weed control possibilities include preventive, cultural, mechanical, and chemical methods. Continuous cultivation of a single crop or crops having similar management practices allows certain weed species to become dominant in the system and, over time, these weed species become hard to control. The care taken that weeds do not need to go to seed, that harvesting equipment is not transporting weed seeds, and that clean seed is used for all crops in the rotation; is an integral part of a weed program. Combining weed control method can help keep weed damage before economic threshold levels and shall be performed rather than a separate control method.

Keywords: soybean, weed, weed control

Introduction
The soybean (*Glycine max* L.) is the most important grain legume crops in the world in terms of total production and international trades. Soybean is an erect bush, leafy annual legume classification under family fabeacea and sub family papillonacea. It is short day plant also self-pollinated and completely self-fertile with less than 1% cross pollinated. It has relatively a wide adaptability to many geographically different regions and is productive per unit area as compared to those closely related crops. Soy bean is C_3 plants that grow well in tropical, sub-tropical and temperate climates. Its germination nature is epigeal and the crop has tap root system (Seyoum Assefa, 2010) [23].
Weeds are a major detriment to soybean yield, although they can be controlled directly by chemical or mechanical treatments or indirectly by agricultural practices, such as crop rotation and soil tillage (Oerke, 2006).Weed control plays an important role in raising the productivity of crops. The presence of weeds is causing a shortage of the crop up to 40% (Soliman *et al*., 2015).
Successful weed control is most important factor for fruitful soybean production, because losses due weeds have been one of the major limiting factors in soybean production. Weeds compete with crop for light moisture and nutrients, with early-season competition being the most critical. Being arainy season crop soybean faces severe weed competition during early stages of crop growth, resulting in a loss of about 40-60 per cent of the potential yield, depending on the weed intensity, nature, environmental condition and duration of weed competition (Kachroo *et al*., 2003). Adverse weather conditions limit the use of tools and implements for clearing weeds in the field. On environmental grounds, emphasis has been given to judicious combinations of cultural and chemical methods of weed control. Therefore, integrated weed management system is a desired practice that aims at reducing the dosage of herbicide to be applied with mechanical weeding, which will help in managing weeds in a best way for realizing to sustain and boost the production of soybean. Similar work has been done by Idapuganti (2003) and Singh (2007) [5].

Objective
To review on weeds and weed control methods in soybean

Literature Review

Competition between soybean and weeds for biotic factors

The biotic factors that determine the increased competitiveness of certain species over others are: plant size and architecture, growth rate, extension of root system, dry mass production, increased susceptibility to environmental elements (such as frost and dry spells), greater leaf area index and greater capacity for production and release of chemicals with all elopathicproperties (Silva, A *et al*. 2007) [29].

Morpho physiological traits of plants influence the competitive relationship between crop and weeds. Plant height and development cycle, for example, are features that have been positively associated with competitive ability in soybean; cultivars with higher cycle length and height reduce seeds production and size of weed species due to the increase incompetitiveness of the crop (Bennett, A. C, & Shaw, D. R. 2007) [4, 15]. Moreover, yield losses due to competition tend to be higher the more similar are the individuals, i.e. their morpho physiological traits, reaching maximum stress within the same species, because in this case neighboring plants compete for the same resources and occupy the same ecological niche (Radosevich, S, Holt, J, & Ghersa, C. 2007) [26].

Weed of soybean

The major weeds in soybean are grouped in to two major classes, broad leaved weeds and grasses and sedges.

Grasses and sedges

Generally, perennial grasses are the most problematic weeds of soybeans. They cause significant damage and difficult to control. Such weeds include common cocklebur (*Xanthium pensylvanicum*), giant foxtail (*Setaria faberii*), sword grass (Imperator cylindrical), Johnson's grass (*Sorghum halepense*) and Couch grass (*Cynodon dactylon*) (Daugovish *et al*., 2003) [8]. They form extensive underground vegetative system which makes them hard to control. Sedges (*Cyperus rotundus*) and (*C. esculentus*) are also difficult to control, yet cause a lot of damage to soybeans. Apart from competition of moisture, carbon dioxide, light and nutrient; they have allelopathic effects on soybeans (Drost and Doll, 1980; Jannink *et al*., 2000) [11, 15]. Perennial weeds usually have the ability for vegetative reproduction from underground parts. These are also organs for growth after cutting and they are storage organs for food reserves. Therefore they require deep cultivation which brings the underground prop gules to the surface and expose them to desiccation by the sun and wind (Drost and Doll, 1980) [11].

Broad leafed weeds

Broad-leafed weeds are not as detrimental as the grasses and sedge in soybean production. However, they cause some damage and should not be over looked. Some produce many seeds making then difficult to control e.g. lamb squatters (*Chenopodium album*). Other serious broad-leafed weeds common in soybean fields include spiny Amaranth (*Amaranthus spinosus*) and morning glory (*Convolvulus arvensis*). Annual weeds can be dealt with by repeated shallow cultivation. Common weeds worldwide have been given by (Joshi, 2001).

Effects of Weed on Soybean Production

Soybean (*Glycine max*) is an important food crop for human consumption whose yield is up to 80% is lost due to weed competition in many parts of the world (Daugovish *et al.*, 2003) [8]. (Jannink *et al.*, 2000) [15] reported that root and shoot interference is the main factors that cause soybean yield reduction. Weeds that germinated at the same time as soybeans grow faster and maintain a canopy above and below the top of the soybean canopy. Therefore they intercept photosynthetically active radiation (PAR) at the expense of soybeans. This results to elongation of soybean stems with a decrease in diameter, causing lodging. Soybean are not strong competitors in the early part of the season, therefore weeds out grow them. If the crop is not kept weed free, light competition takes place after 4 weeks when the weed grow taller than soy beans and intercept photo synthetically active radiation PAR (Jannink *et al*., 2000) [15]. Sink strength (rate of change in weight of substance for a plant part) is profoundly affected by the shading effect of weeds in soybean (Bradley *et al*., 2002) [3].

Weed Control Methods in Soybeans

Preventive method

It is harder to control weeds once they establish themselves, so preventing foreign weeds from entering a new area is usually easier and costs less than controlling after they have spread. According to (Silva *et al*., 2007) [29] the preventive control of weeds is the use of practices aimed at preventing the introduction, establishment and, or, spread of certain problematic species in areas not yet infested by them. These areas can be a country, a state, a municipality or a piece of land inside the farm. In federal and state levels, there are laws regulating the entry of seeds into the country or state and its internal commercialization. Under these laws are the tolerable limits of seeds of each weed species and also the list of prohibited seeds per crop or crop group. Locally, it is the responsibility of individual farmers or cooperatives, to prevent the entry and spread of one or more weed species that may become serious problems for the region. In summary, the human element is the key to preventive control. The efficient occupation of the agroecosystem space by the crop reduces the availability of appropriate factors for growth and development of weeds, and can be considered an integration between preventive and cultural method. Choosing the right cultivars is actually the first step in successfully establishing a crop. In the soybean case, there is a large number of cultivars adapted to different regions of the world. Some of the measures that can prevent the introduction of the species are: use of high purity seeds, clean thoroughly machines, harrows and harvesters; carefully inspect seedlings acquired with soil and also all the organic matter (manure and compost) from other areas; clean irrigation canals; quarantine of introduced animals, etc. (Radosevich *et al*., 2007) [26] and (Chauhan *et al*. 2012) [5]. Affirm that most crops have their seeds contaminated with weeds, especially when weed seeds resemble the size and shape of crop seeds. Contamination usually happens during the time of crop harvesting when weeds that have life cycles similar to those of crops set seeds. When even a small amount of weed seeds is present, it may be enough for a serious infestation in the next season. The idea should be to minimize the weed infestation area and decrease the dissemination of weed seeds from one area to another or from one crop to another. Control of weed species is

achieved by reducing plants and propagules to the point at which their presence does not seriously interfere with an area of economic use. The planning of post infested weed control programs should be done in such a way that the build-up of weed seeds is reduced drastically within a short period. Proper care should be taken to restrict the weed seed bank size in the area by using integrated methods of weed control. In undisturbed or not ill systems, seeds of weeds and volunteer crops are deposited in the topsoil (Locke *et al*., 2002) [19]. Therefore, an appropriate strategy is needed to avoid high weed infestations and to prevent unacceptable competition with the emerging crop (Locke *et al*., 2002) [19].

Cultural control

The competitive ability of weeds largely depends on the time of emergence in relation to the soybean, in such a way that, if the crop germinates faster, and also occurs a delay on the emergence of weeds, competition will be reduced (Radosevich *et al*., 2007) [26]. According to (Silva *et al*., 2007) [29] cultural control is the use of common practices for the proper management of water and soil as crop rotation, variation of crop row spacing, living mulches, etc. Amending the soil, neutralizing the aluminum content and increasing the pH, favors the crop and not certain weed species adapted to acid soils conditions and high contents of Al. Fertilization applied at the planting furrow is a common practice, and also favors soybean, so the fertilizer do not stand so close to the weeds in the inter-rows. These practices help to reduce the seed bank of weeds. It consists, therefore, in using their own ecological traits, both from crops and weeds, in order to benefit the establishment and development of crops.

One of the main practices is crop rotation. Its benefits depend on the selection of crops and their sequence in the system. Continuous cultivation of a single crop or crops having similar management practices allows certain weed species to become dominant in the system and, over time, these weed species become hard to control (Chauhan *et al*., 2012) [5]. According to (Kelley *et al*., 2003) [16]. Soybean production is improved by using crop rotation as a management practice.

Numerous studies have shown decreased yield when soybean was grown continuously in monoculture than when rotated with another crop (Crookston *et al*., 1991) [7], (Meese *et al.,* 1991) [20], (West *et al.,* 1996) [32]. In the short-term, benefit of crop rotation was increased soybean yield, which would likely increase soybean profitability. In the long-term, rotations with high residue-producing crops, such as wheat and grain sorghum, significantly increase total soil C and N concentrations over time, which may further improve soil productivity (Kelley *et al*., 2003) [16].

Variation of the spacing or plant density in the row is another practice that can contribute to the reduction of weed interference on the crop, depending on the architecture of the cultivated plants and weed species. The reduction of spacing between rows often provides competitive advantage for most crops over shading sensitive weeds. In this case, by reducing the spacing between rows, provided it does not exceed the minimum limit, there is increased light interception by the canopy of cultivated plants. This effect is dependent on factors like the type of species to be cultivated, morpho physiological traits of genotypes, weed species present in the area and season and weather conditions at the time of its emergence, as well as environmental conditions (Herbert *et al*., 1984) [14], (Anaele *et al*., 1992), (Knezevic *et al*., 2003) [17].

The main goal of using cover crops for weed control is replacing an unmanageable weed population with a manageable cover crop. This is accomplished by selecting the phenology of the cover crop to preempt the niche occupied by weed populations Teasdale, J. R (1996) [30]. They have been used to manage weeds in soybean (Ateh, C. M, & Doll, J. D. (1996) [2], (Liebl *et al*., (1992) [18], (Moore *et al*., 1994) [22], Samarajeewa KBDP Horiuchi T, Oba S. Finger millet (2006). According to (Silva *et al*., 2007) [29] The spacing and sowing density are further tools in cultural management and allow less weed interference in soybeans, basically to plants with low tolerance to shade. Usually, the density experiments for weed control are conducted in graminae: maize, rice and also wheat. However, even in soybean, studies conducted in Brazil show that reducing the spacing between rows of crops (e.g. 60 cm to 30 cm) interferes with the period of weed control (Melo *et al*., 2001) [21]. The competitive ability of weeds largely depends on the time of emergence in relation to the soybean, in such a way that, if the crop germinates faster, and also occurs a delay on the emergence of weeds, competition will be reduced (Radoservich *et al*., 2007) [26].

According to (Silva *et al*., 2007) [29], cultural control is the use of common practices for the proper management of water and soil as crop rotation, variation of crop row spacing, living mulches, cover crops etc. Amending the soil, neutralizing the aluminum content and increasing the pH, favors the crop and not certain weed species adapted to acid soils conditions and high contents of Al. Fertilization applied at the planting furrow is a common practice, and also favors soybean, so the fertilizer do not stand so close to the weeds in the inter-rows. These practices help to reduce the seed bank of weeds. It consists, therefore, in using their own ecological traits, both from crops and weeds, in order to benefit the establishment and development of crops. One of the main practices is crop rotation. Its benefits depend on the selection of crops and their sequence in the system. Continuous cultivation of a single crop or crops having similar management practices allows certain weed species to become dominant in the system and, over time, these weed species become hard to control (Chauhan *et al*., 2012) [5].

Mechanical control

According to Silva *et al*. (2007) [29] weed plucking, or weeding, is the oldest method of weed control. It is still used to control weeds in home gardens and in the removal of weeds between crop rows, when the main method of control is the use of a hoe. The manual weeding made with a hoe is very effective and still widely used in our agriculture, especially in mountainous regions, where there is subsistence agriculture, and for many families, this is the only source of work. However, in a more intensive agriculture in larger areas, the high cost of manpower and the difficulty of finding workers when necessary and in the desired quantity, make this method only complementary to others, and should be done when the weeds are still young and the soil is not too humid. It can assume great importance in seed production fields, being a good alternative for using isolated or as a complement for other control methods (Gazzeiero *et al*., 2003) [12].

Mechanized cultivation, made by cultivators pulled by animals or tractors, is widely accepted in Brazilian

agriculture, being one of the main methods of weed control on properties with smaller areas planted. The main limitations of this method are the difficulty of controlling weeds in the crop rows, low efficiency when performed in wet conditions (wet soil), and it is also inefficient to control weeds that reproduce by vegetative parts. However, all the annual species, when young (2-4 pairs of leaves), are easily controlled in conditions of heat and dry soil. Cultivation breaks the intimate relationship between root and soil, suspending the absorption of water, and exposes the roots to unfavorable environmental conditions. Depending on the relative size of weeds and crops, the displacement of the soil on the row, using special hoe cultivators, can cause the burial of seedlings and there by promote weed control even in the rows of the crop (Silva *et al*., 2007) [29].

Biological control

Biological control is the use of natural enemies (fungi, bacteria, viruses, insects, birds, fish, etc.) capable of reducing weed populations, reducing their ability to compete. This is maintained by the population balance between the natural enemy and the host plant. It should also be considered as biological control the allelopathic inhibition of weeds (Silva *et al.*, 2007) [29].

According to Charudattan & Dinoor (Charudattan, R, & Dinoor (2000) [6], bioherbicide is defined as a plant pathogen used as a weed-control agent through inundative and repeated applications of its inoculum. In the United States and many other countries, the prescriptive use of plant pathogens as weed control agents is regarded as a "pesticidal use" and therefore these pathogens must be registered or approved as biopesticides by appropriate governmental agencies.

Currently, one fungus species is registered as bioherbicide in the United States for use in soybeans. Collego®, based on *Colletotrichum gloeosporioides* f.sp. *aeschynomene*, is used to control *Aeschynomene virginica* (northern jointvetch), a leguminous weed, in soybean and rice crops in (Arkansas *et al*., 2000) and Charudattan & Dinoor (2000) [6] also state that, among the limitations of biocontrol of weeds by plant pathogens, the most important are the limited commercial interest in this approach to weed control due to the fact that markets for biocontrol agents are typically small, fragmented, highly specialized, and consequently the financial returns from biocontrol agents are too small to be of interest to big industries; and the complexities in production and assurance of efficacy and shelf-life of inoculum can further stifle bioherbicide development. For instance, the inability to mass-produce inoculum needed for large-scale use is a serious limitation that has led to the abandonment of several promising agents. The authors conclude that plant pathogens hold enormous potential as weed biocontrol agents.

In addition to the use of plant pathogens as biocontrol agents, it is likely that pathogen-derived genes, gene products, and genetic mechanisms (e.g., hypersensitive plant cell death and herbicidal biochemicals) will be exploited in the near future to provide novel weed management systems. On the other hand, the present over-reliance on chemical herbicides and the tendency to base weed-management decisions purely on economic considerations, at expense of the exclusion of ecological and societal benefits, is a serious limitation that could stifle biological control (Arkansas *et al*., 2000) and Charudattan & Dinoor (2000) [6].

Chemical control

There are several advantages in using herbicides: pre-emergence control, eliminating the weeds precociously; hits targets that the hoe or cultivator does not reach, like the weeds in the crop row; reduces or eliminates the risk of damage to the roots and to young plants. Perennial weeds; reduces the need for labor; increases the speed and efficiency of the control operation per unit area, reducing the cost per treated area; controls the weeds for a longer period, when the use of a cultivator is impossible in view of the crop growth; and can be used in rainy periods, when the mechanical control is not efficient and when labor is required for other activities. However, it has the disadvantage of requiring skilled labor, because, if done improperly, can poison the crop, the environment and, especially, the applicator himself.

Although herbicides are very effective in controlling weeds, they may promote the development of resistant biotypes, a fact that would further exacerbate the problem within an area Zimdahl, R. L. (2000) [35].

According to (Oliveira Jr. *et al*., 2006) [24] the most common strategies used in the management of both cover crops and weed vegetation in areas of no-tillage are reduced to three: desiccation immediately before sowing, between seven and ten days before sowing or anticipated drying. These authors undertook a study aimed to evaluate the interaction between tillage systems and weed control in post emergence in soybean with these three strategies. They concluded that, although desiccation in different management systems have been effective, the anticipation of desiccation in anticipated management favored the emergence and initial soybean development, providing greater productivity gains, given the infestation conditions. The management system also affected the flow of weed emergence after soybean emergence, with fewer reinfestations in the anticipated management system, due to the control of initial flows given by the second application of this management system. Management applied at planting and ten days before planting, hindered the development of soybean, resulting in lower productivity, while anticipated management provided the highest yield.

Procópio *et al*. (Procópio *et al*., 2006) [25]. Carried out a study in which they compared the effects of tillage systems on the control of the weeds *Digitaria insularis*, *Synedrellopsis grisebachii* and *Leptochloa filiformis* before soybean planted in no-till. The authors found satisfactory control and prevention of regrowth of *D. insularis* and *L. filiformis* when glyphosate was applied five days prior to soybean planting or when the sequential application of glyphosate and paraquat + diuron was done. Sequential applications of the mixture paraquat + diuron were not effective in controlling However, it has the disadvantage of requiring skilled labor, because, if done improperly, can poison the crop, the environment and, especially, the applicator himself. Although herbicides are very effective in controlling weeds, they may promote the development of resistant biotypes, a fact that would further exacerbate the problem within an area (Zimdahl *et al*., 2000) [35].

According to Arregui *et al*. (2006) [1], there are several soil-applied broadleaf herbicides that effectively control weeds like *Ipomoea spp*., *Commelinaspp*. and Sidespins. Chlorimuron and sulfentra zone reduce Ipomoea spp. S. spinosadensity decreased with imazaquin, metribuzin and

sulfentrazone applications and with cloransulam and diclosulam (Reddy *et al.*, 2000) [27].

Integrated weed management

The concept of Integrated Weed Management (IWM), a component of Integrated Pest Management, has been proposed (i) to decrease the density of weeds emerging in crops,(ii) to reduce their relative competitive ability (in order both to preserve crop yields and to limit the replenishment of weed seed bank), and (iii) to control emerged weeds using non chemical techniques, with the overall aim of reducing the need for herbicide application at the cropping system level (Deytieux *et al*., 2012) [9]. IWM advocates the use of all available weed control options such as: plant breeding, fertilization, crop rotation, tillage practices, planting pattern, cover crops and mechanical, biological and chemical controls. To define the correct weed management strategies, it is necessary to know the ability of the weed species, in relation to the crop, to compete for water, light and nutrients, which are factors responsible for decreasing crop yield (Silva *et al.*, 2007) [29]. Usually, it is not taken into consideration that a good program of weed management should allow for maximum production in the shortest time, the maximum sustainable production and minimal environmental and economic risk. (Wilson *et al*,. 2009) [33].

Plant height significantly affected by different weed control treatments as compared to weedy check. The highest plant height was observed in weed free which found at par with hand weeding at 15 and 35 DAS, imazethapyr @ 75 g a.iha-1andquizalofop-ethyl @ 40 g a.i ha-1in combination with hoeing at 35 DAS. This might be due to the increased availability of nutrients and lesser competition of weeds which could possibly result in better accumulation of photosynthates. Similar result has been reported by Thakur (2008) [31] and Dhane *et al.* (2010) [10]. The maximum number of branchesplant-1 was found in weed free which was statistically at par with hand weeding at 15 and 35 DAS. However, highest number of pods was recorded in weed free which was statistically at par with hand weeding at 15 and 35 DAS, imazethapyr @ 75 g a.iha-1 and quizalofop-ethyl @ 40 g a.i ha-1in combination with hoeing at 35 DAS. It might be due to reduction in dry matter production by weeds under herbicidal and cultural treatments (hoeing) that subsequently increased nutrient and moisture availability to the soybean crop. Similar results were reported by Gupta and Saxena (2008) and Dhane *et al.* (2009) [10]. Mechanical weeding improved the soil aeration and increased nutrient availability to the crop through active mineralization and decomposition. It was also accordance with Seema *et al*., 2014 [28], Prasad and Pandey, 2005. Seed and straw yields are significantly influenced by different weed control treatments as compared to weedy check (Table 2). The maximum seed and straw yield was obtained with weed free treatment followed by hand-weeding at 15 and 35 DAS. Among various herbicidal weed control treatments, imazethapyr @ 75 g a.i ha-1+ hoeing (35 DAS) recorded maximum seed and straw yield which was found to be at par with quizalofop-ethyl @ 40 g a.i ha-1+ hoeing (35 DAS). It might be due to the fact that both these herbicides when applied as post-emergence suppresses the weed growth efficiently which is supplemented by hoeing at the crucial stage of crop growth which checks the weed growth and resulted in higher seed and straw yield. Similar findings have been reported by Dhane *et al.* (2009) [10], Yadav and Shaikh (2009) [34] and Wadafale *et al.* (2011).

Summary and Conclusion

Soybean is among the most promising source of high quality, but low cost of protein in developing world at large. It has relatively a wide adaptability to many geography this multipurpose crop is very popular industrially due to its oil and protein rich seeds from which various basic food items and other products are processed or synthesized for different uses basically different regions and is productive per unit area as compared to those closely related crops. Losses due to weeds have been one of the major limiting factors in soybean production, where, weeds compete with soybean for light, moisture and nutrients with early- season competition, being the most critical. Perennial grasses are the most problematic weeds of soybeans. They cause significant damage and are difficult to control. Broad-leafed weeds are not as detrimental as the grasses and sedge in soybean production.

Soybean are not strong competitors in the early part of the season, therefore weeds out grow them. Weeds in the field at harvest also result in reduced grades (quality).Weeds also have effect on the use of fertilizer because they compete with the crop for nutrients. Fertilizers encourage weeds growth therefore they should not be applied until the first weeding has been done. Weed management involves activities directed at the weeds (direct management) and, or, the system formed by soil and crop (indirect management).Weed control possibilities include preventive, cultural, mechanical and chemical methods.

However, to maintain the sustainability of agricultural systems, it is important to integrate these control measures by observing the characteristics of soil, climate and socioeconomic aspects of the producer. It is harder to control weeds once they establish themselves, so preventing foreign weeds from entering a new area is usually easier and costs less than controlling after they have spread. Choosing the right cultivars is actually the first step in successfully establishing a crop.

Continuous cultivation of a single crop or crops having similar management practices allows certain weed species to become dominant in the system and, over time, these weed species become hard to control. Soybean production is improved by using crop rotation as a management practice. Mechanical control is used to control weeds in home gardens and in the removal of weeds between crop rows, when the main method of control is the use of a hoe.

Although herbicides are very effective in controlling weeds, they may promote the development of resistant biotypes, a fact that would further exacerbate the problem within an area. The care taken that weeds do not need to go to seed, that harvesting equipment is not transporting weed seeds, and that clean seed is used for all crops in the rotation; is an integral part of a weed program. Therefore, combining weed control method can help to keep weed damage before economic threshold levels.

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