Controlling invasive alien species *Vachellia nilotica* with triclopyr herbicide in Baluran National Park

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Abstract. *Vachellia nilotica* (Acacia nilotica), as an invasive alien species (IAS), was introduced to Baluran National Park from the Bogor Botanical Gardens in 1969. The purpose was for firebreak to prevent jumping fires from the savanna to the teak forests plantation. However, unexpectedly *V. nilotica* growth was uncontrollable and invaded the 6000 ha savanna. The rapid growth of this weed has killed the grass in the savanna leading to a decline in the Banteng population in Baluran National Park from 325 in 1998 to 22 in 2011. Since the 1980s, research on *V. nilotica* control has been carried out by various universities and research institutions in Indonesia but has not yet obtained an effective and efficient control method. The study aimed to investigate the efficacy of herbicide with the active ingredient of triclopyr by stump brushing to control *V. nilotica*. Ten triclopyr herbicide concentrations with a solution of diesel and water were tested. The results showed that 1% triclopyr concentration in diesel oil could control 100% of *V. nilotica* weeds, while water solutions could only control 50% of *V. nilotica* weeds.

1. Introduction

*Vachellia nilotica* (L) P. J. H. Hurter & Mabb (synonym *Acacia nilotica* (L.) Willd. Ex Del.) is commonly known as *babul* or *kikar*. It is an Arabic gum-producing plant and has been known worldwide as a multipurpose plant [1-3]. This plant is endemic to dry areas in Africa, West Asia, India, Myanmar, and Sri Lanka [4].

*V. nilotica* was first introduced from the Indian Calcutta Botanical Gardens to the Bogor Botanical Gardens in Indonesia in 1850 to produce gums. However, during its development in Bogor, this plant only yields very little gum [5]. In 1969 *V. nilotica* was introduced to Baluran National Park for fire breaks to protect fire jumps from the savanna to the Perum Perhutani (Government-owned teak forest) teak forest bordering the Baluran National Park. Besides, *V. nilotica* was also introduced to West Bali National Park and South Sulawesi, yet its growth and development are not invasive in these two areas [6-7].

The growth and development of *V. nilotica* in Baluran National Park became so invasive that this plant became an invasive foreign weed and invaded the savanna area of 6000 ha from the total savanna...
area of 12,000 ha. The rapid growth and development in Baluran National Park are caused by the biological characteristics of the plant for resistance to fire, drought, and rapid seed dispersal. The fallen ripe pods in the dry period were eaten by the mammals in Baluran National Park, such as wild buffaloes, bulls, and deer, enter the digestive tract of animals. Yet, the defecated seeds do not lose viability. In 100 grams of wild buffalo feces, there are 45 ± 26 V. nilotica seeds; in bull faces, there are 62 ± 42 seeds; and in deer feces, there are 11±9 seeds [8]. Other than through the help of mammals, rainwater run-off possibly disperses V. nilotica seeds over a considerable distance.

Invasion of V. nilotica in the savanna area resulted in very little grass remaining lead to a smaller feed carrying capacity for mammals and finally decreased Banteng (Bos javanicus) populations. The population of Banteng in 1998 was still 325, but thirteen years later, in 2011, only 22 [9].

In its expansion in the field, V. nilotica associates with beneficial soil microbes, Rhizobium sp. and Arbuscular Mycorrhizae Fungi (AMF), to accelerate plant growth [3, 10, 11]. Rhizobium is a bacteria that can fix nitrogen from the air and be used by the host plant to accelerate plant growth. AMF grows symbiotic mutualism with its host plant and helps absorb nutrients, especially P and other elements such as N, K, Ca, Mg, and increases plant growth [3, 12-15].

In the area of forest land that has been overgrown by V. nilotica, only a few vegetation grows on the forest floor and around the V. nilotica plant due to its allelopathic factor. Studies showed that allelopathy inhibits germination and growth of many species such as corn, peanut, wheat, and green beans [10, 16, 17] and also Trigonella foenumgraecum L [18].

The V. nilotica plant is one of Australia’s worst invasive alien species (IAS) due to its invasive character, potential distribution, and damaging economic and environmental effects. It invades an area of 6.6 million ha in the arid and semi-arid zone of Queensland [19].

Controlling V. nilotica in Baluran National Park has been carried out since the 1980s, including physical such as logging, demolition, burning; mechanical such as bulldozer; and chemicals such as herbicides [20]. However, none of these controls are effective and efficient in controlling V. nilotica in Baluran National Park.

Several natural enemies that can act as biological control agents in dealing with V. nilotica include: Bruchidius sahlbergi Schilsky, a seed-eating insect, and Chiasmia assimilis, a leaf-eating insect, Cuphodes profluens; Anomalococcus indicus Ayyar and Cophinforma cause dieback [21-23].

The purpose of this study was to determine the efficacy of herbicide with active ingredient triclopyr to control invasive foreign plants V. nilotica in Baluran National Park.

2. Materials and Methods

2.1. Place and time of research
The study was conducted from May 2011 to October 2012 in Kramat, about 2 km east of the Bekol section office and 12 km from the Baluran National Park office in Batangan, Banyuputih Sub-District, Situbondo.

2.2. Materials and tools
The materials used in this study were herbicides with the active ingredient triclopyr (commercial name Garlon 670 EC, equivalent to 480 g l triclopyr) [24], diesel oil, water, nine years old V. nilotica tree with a diameter range of 9-12 cm. Meanwhile, the equipment used was a 2 L bucket, a 2” paintbrush, a tape measure, and a chain saw.

2.3. Stump brushing procedure
Nine-year-old V. nilotica trees with a diameter range of 9-12 cm were cut at a trunk of 10 cm above the ground to ease movement of the chain saw when cutting tree trunks. The stems and twigs of the felled are cut into short pieces with a length of 1.5 m. Those pieces were then collected at the edge of the research plot area.

The top surface and bark of V. nilotica stumps were smeared with triclopyr in a diesel oil solution (stump brushing) with a concentration of 0 g triclopyr L⁻¹ diesel oil as much as 60 ml. This treatment was repeated 20 times. After that, the same thing was repeated with a concentration of 0.96 g triclopyr
L-1 diesel oil, 4.8 g triclopyr L-1 diesel oil, 32.4 g triclopyr L-1 diesel oil, 60 g triclopyr L-1 diesel oil, 120 g triclopyr L-1 diesel oil, and 240 g triclopyr L-1 diesel oil (Table 1). In addition, Tricyclopir dissolved in water was also treated with a concentration of 0 g triclopyr L-1 water, 0.96 g triclopyr L-1 water, and 4.8 g triclopyr L-1 water. The concentration of the active ingredient triclopyr and the formulation used in this study are presented in Table 1.

2.4. The parameters observed

The parameters observed were the percentage of tree mortality and the percentage of shoots on V. nilotica trees for six months.

2.5. Research design and data analysis

The research design was a completely randomized design with ten (10) treatments and 20 replication per treatment (Table 1). Data were analyzed with statistical software of JMP Start Statistics 14, and data that showed significant differences were further tested by the Duncan test.

2.6. Planting grass

At the end of the 6th month (after the observation of the efficacy ended), shoots of the survival V. nilotica plants were cut, and the stumps were smeared with a 1% concentration of triclopyr in a diesel oil solution. The grass that grows in the study area is sprayed with Roundup herbicide with a concentration of 5 ml/L of water. Grasses in the study area were killed to facilitate one grass species, Dichantium caricosum growing without competition with other grasses. At the beginning of the rainy season, the area was planted with D. caricosum grass with the spacing of 1 x 1 m with vegetative materials measuring 20 x 20 cm and a soil thickness of 10 cm.

3. Results and Discussion

The treatment of herbicide triclopyr on the stump brushing with concentrations of 1, 6.75, 12.5, 25, and 50% significantly killed 100% of the V. nilotica.

V. nilotica was compared to the control after six months of the treatment (Table 1). Meanwhile, triclopyr treatment with water solution was less effective in controlling V. nilotica with the percentage of plant mortality below 50% (Table 1).

The 1% triclopyr concentration dissolved in diesel fuel significantly killed plant samples (100%) compared to water solutions (50%) (Table 1). It was most likely due to diesel oil, one carrier (solvent) that allows the herbicide to penetrate the plant barks. The surface area of the smeared plant bark (meristem surface area) in the stump brushing method was wider than the surface area of the smeared stump. It was almost similar to the stem brushing technique, where the efficacy was greatly influenced by the applied surface area and the plant diameter [25].

Chemical control of woody plants in the forestry sector besides the stump brushing mentioned above, there are two other techniques often used: stem injection (herbicide injected into the tree trunk) and stem brushing, spraying herbicide to the basal tree [26-27]. Chemical control with herbicides is one way of controlling, especially for large areas and low labor resources [27].

The herbicide with the active ingredient triclopyr is absorbed by the bark and surface of the cut stem and translocated throughout the plant tissue. Then triclopyr is accumulated in the meristem growth area [28, 29]. Furthermore, triclopyr can also be absorbed by plant leaves and roots. Because this herbicide is systemic, the active ingredient is translocated throughout the plant tissue and will kill the plant by disrupting the auxin hormone [29].

One thing to consider in controlling V. nilotica by applying tree stumps is that the herbicide solution should be evenly distributed on the surface of the cambium/bark of the cut stump surface and the surface of the stump bark. It is shown clearly in the area where the shoot grows, namely on the upper stump bark and the bark of the plant from the soil surface to the cutting surface (10 cm) in the control treatment as well as in other treatments where the bud is still growing.
### Table 1. Percentage of V. nilotica tree deaths and shoots after six months of tree stump brushing application.

| No. | Active Ingredient of Triclopyr (g L\(^{-1}\) solvent) | Formulation Concentration (%) | Solvent | Tree Death | Tree Shoot |
|-----|-----------------------------------------------------|--------------------------------|----------|------------|------------|
|   1 | 240                                                 | Diesel oil 50                  | 100 a    | 0 a        |            |
|   2 | 120                                                 | Diesel oil 25                  | 100 a    | 0 a        |            |
|   3 | 60                                                  | Diesel oil 12.5                | 100 a    | 0 a        |            |
|   4 | 32.4                                                | Diesel oil 6.75                | 100 a    | 0 a        |            |
|   5 | 4.8                                                 | Diesel oil 1                    | 100 a    | 0 a        |            |
|   6 | 0.96                                                | Diesel oil 0.2                  | 50 b     | 50 b       |            |
|   7 | 0                                                   | Diesel oil 0                    | 0 c      | 100 c      |            |
|   8 | 4.8                                                 | Water 1                        | 50 b     | 50 b c     |            |
|   9 | 0.96                                                | Water 0.2                      | 0 c      | 100 c      |            |
|  10 | 0                                                   | Water 0                        | 0 c      | 100 c      |            |

Remarks:
1. Numeric followed by the same letters in the same column are not significantly different at p < 0.05 according to Duncan test
2. Data were analyzed after arcsin transformation

Applying a mixture of diesel oil and water for the herbicide triclopyr, one thing to consider is the interval between cutting and brushing. Diesel oil solvent can be used immediately after cutting the stems or after several days of cutting, while the water mixer can only be used shortly after cutting the stems [20].

Stump brushing combines physical and chemical control, which generally grasps a 95-100 % success rate. The cut and brush method's efficiency is independent of seasonality and humidity and requires only a small amount of herbicide per tree. The main problem is that it requires human resources and diesel oil in large quantities. The solution to this problem is to modify the stump brushing tool into a more efficient control tool by combining cutting and brushing into a single piece of equipment. Therefore, after cutting, the tools immediately spray herbicide. Solar oil is another significant input cost so, using used diesel should overcome this problem [25].

Triclopyr is a systemic and selective herbicide used to control woody and herbicidal broadleaf plants along roads, forests, savanna, and parks [19, 29]. The selectivity property makes triclopyr often applied to savanna areas because this herbicide does not kill the grasses, the main crop in the area [19, 29].

Triclopyr is thought to have only a low level of poisoning to birds and mammals [29]. Triclopyr would not be present in sufficient quantities in animal feed which could have acute or chronic effects [30]. The content of esters and amines in the herbicide triclopyr is degraded by sunlight, metabolites, and microbial hydrolysis. The acid and amine formulations of triclopyr will be tightly bound in the soil so that the two compounds are not mobile.

Based on the observations of the author and Baluran National Park rangers, the advantage of controlling stump brushing compared to stem brushing is that the grass could rapidly grow because there is no shade. In addition, mammals can also run freely without the risk of crashing into trees when there are outside disturbances.

At the end of the observation, six months after the brushing treatment, the surviving V. nilotica trees were cut, and their stumps were smeared with a 1% concentration of triclopyr with solar solvent to kill all remaining trees. After that, the roundup was sprayed in the sites to kill all the grasses, so the planted Lamuran Putih grass (D. caricosum) grows and develops without the competition of other grasses. Then, at the beginning of the rainy season, lamuran putih grass should be planted with a block sod size of 20 x 20 cm and a thickness of 10 cm with a spacing of 1 x 1 m. Finally, the 8th month after the planting, the study site was covered with Lamuran Putih grass (Figure 1).
Figure 1. Growth of 6-month-old *D. caricosum* grass in Kramat Baluran National Park.

4. Conclusion
Stump brushing application of triclopyr herbicide at concentrations 1, 6.75, 12.5, 25, and 50% with diesel solvent can kill *V. nilotica* by 100%, while triclopyr herbicide with water solvent is less effective in controlling *V. nilotica*.

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