Growth, Yield and Phytochemical Constituents of *Arctium lappa* L. in Response to Phosphorous and Potassium Fertilizers Application

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Abstract**—** Burdock (*Arctium lappa* L), is a medicinal plant with many therapeutic values but its cultivation practice is given less attention causing pressure on its wild population. A two separate complete randomized design pot experiment with five treatments of phosphorous (Triple superphosphate 20%) at five levels (140, 210, 280, 350 and 420 kg/ha) and potassium (Potassium Chloride 50%) at five levels (210, 315, 420, 520 and 630Kg/ha) with a basal application of Nitrogen fertilizer (Urea,160 Kg/ha) replicated four times was conducted. Fertilizer treatments were split into two equal doses at seedling transplant and four weeks after transplant. Data on growth and yield were collected and analyzed using SAS software. Test results were significant ($p<0.05$) in growth parameters in response to phosphorous and the number of leaves in potassium treatments. However, there was no significant difference ($p>0.05$) on yield parameters due to fertilizer application except for root length. Phytochemical screening indicates the presence of Tannins, flavonoids, Terpenoids, glycosides, and phenols across treatments. Crude lipid and ash content were not significant ($p>0.05$) but there was a significant difference ($p<0.05$) on crude fibre content in response to fertilizer treatments.

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Keywords**—**Burdock, cultivation, fertilizer treatments, growth, yield, phytochemicals

I. Introduction

Burdock (Arctium lappa L.) is an indigenous medicinal herb of the Asian continent and native to Eurasia, which belongs to the family Asteraceae. It has many therapeutic values [1]. Traditionally a mixture of the species with oil and honey is applied on the chest for treatment of common cold [2]. The fruits are used as blood purify and for the treatment of respiratory diseases [3]. The leaves are used for the treatment of rheumatic pain, sunstroke, snake, and scorpion bites [4-6]. The Roots are used in veterinary medicine for the treatment of mastitis while the infusion extract of the whole plant can be applied against endoparasite in poultry [7]. The species is also consumed as a vegetable in the form of salad and stew because of its high nutritional composition [8].

The demand for this plant keeps increasing without assurance of consistent supply since most of its supply is mostly dependent on the wild causing pressure to its natural habitat. The cultivation of this species is given less attention even in the region of its origin not alone in South Africa. South Africa still depends mostly on the importation of the plant materials for medicine, with little assurance of consistent supply to satisfy the demand of the needy population. Also the non-awareness of this plant as a potentials vegetable to help address the issue of food security to our communities not alone its cultivation practices. Therefore, the cultivation of this species in South Africa is imperative. This study was therefore undertaken to investigate the influence of potassium and phosphorus fertilizer application on the growth, yield and phytochemical constituents of this species.

II. Materials And Methods

A. Study Area

The study was conducted at the Research and Teaching Farm, the Agric-Hub, Department of Agriculture Wellington Campus, Cape Peninsula University of Technology (CPUT). The area falls within the Northern part of Wellington at coordinate (S33^{o}37’ E19^{o} 37’), with a Mediterranean climate, and receives about 585 mm of winter rainfall per year. Rainfall is usually from February to November, with the lowest rainfall in February (10 mm) and the highest in June (105 mm). The average daily temperatures for wellington is from 16.5 ^{o}C in July to 28.8 ^{o}C in February.

B. Experimental Layout and treatment application

Burdock seeds (Takinogawa long cultivar) were obtained from "The Seed Collection Pty Ltd" company in Australia (Ferntree Gully, Victoria 3156 Australia with permit N0. P0084124) and nursed in a greenhouse using a plastic tray filled with potting soil, regular watering was done in the morning and evening to keep the soil moist. At three weeks, 100% germination of sown seeds were obtained. At six weeks the seedlings were taken outside for acclimatization for two weeks

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before transplanting to larger pots of 10kg potting soil obtain from standard farm. The soil had a total nitrogen (0.353%) and phosphorous(418mg/kg) with a moderate amount of potassium (3425mg/kg) and pH 7.1. The experiment was arranged in a complete randomized design (CRD) with five treatments (140, 210, 280, 350 and 420 kg/ha^{-1}) of phosphorous (Triple superphosphate 20) and potassium (Potassium Chloride 50%) at five levels (210, 315, 420, 520 and 630Kg/ha^{-1}), supplemented with Urea at160 Kg/ha^{-1} as a source of nitrogen. All treatments were replicated four times. Fertilizer treatments were split into two equal doses at seedling transplant and four weeks after transplant. Irrigation and weeding were conducted as required throughout the cultivation period.

C. Data collection

Data on plant height, number of leaves per plant, leaf length and leaf width were measured and recorded at two weeks' interval until 16 weeks when the first set of leaves starts to collapse. Plant height, leaf length, and broadest width of plant leaves were measured using a meter rule. The number of leaves per plant was numerically counted. At maturity, plants were harvested and washed using tap water. Data on yield was collected on plant biomass, root fresh weight, leaf fresh weight using a Lasec, Radwang wagi`s electronic weighing balance Model: WLC 1/A2/C/2, Made in Poland (EU). Root length and root diameter were measured using a thread and subsequently calibrated on a meter rule.

D. Phytochemical screening and proximate analysis of root and leaf samples of Arctium Lappa L.

Fresh leaves and roots samples at maturity were harvested from the different plant treatments and were used to prepare aqueous root and leaf extracts of *Arctium lappa* L. for the different fertilizer treatments. The different extracts were screened for the presence of phenols, tannins, flavonoids, steroids, terpenoids, saponins, alkaloids and glycoside by the following reactions; Ferric chloride test for tannins, Foam test for saponins, NaOH with dilute acid for flavonoids, 5% ferric chloride solution for phenol, Dragendoff`s and Meyer`s reagent for alkaloids, Chloroform, and acetic acid anhydride with Con Sulphuric acid for steroids, glacial acetic acid with a drop of FeCl3 and Con Sulphuric acid for Glycosides, Chloroform and acetic acid anhydride with Con Sulphuric acid for terpenoids as fully described by [9] in the laboratory of the Department of Chemical and Physical Science Walter Sisulu University of Science and Technology. Proximate analysis of the dry powdered root and leaf samples of *Arctium lappa* L. was carried out using, Sulphuric acid and Sodium hydroxide for Crude fibre, Diethyl ether for Crude lipid and incineration at 550°C for ash content using the method of [10] at the Agric-Hub in the Postgraduate Analytical Laboratory of the Department of Agriculture, Wellington Campus, Cape Peninsula University of Technology.

E. Statistical analysis

Analysis of variance ANOVA at 95% confidence limit and comparison of means was carried out on growth, yield, and proximate analysis data of the plant samples using SAS software (SAS Institute 1999). Means separation was done using Fisher`s Least Significant Difference(LSD) and Duncan Multiple Range Test (DMRT).

III. Results And Discussion

A. Effects of fertilizer treatments on growth parameters of Arctium lappa L

TABLE I: Influence of fertilizer treatments on morphological characteristics of burdock (Arctium lappa L). Values are means of four replicates at (P-value 0.05).

Treatments (kg/ha)	Number of leaves	Plant height(cm)	Leaf length(cm)	Leaf width(cm)
Potassium				
$T_1(k_{210})$[control]	7.00^a	26.94^a	17.75^a	15.25^a
$T_2(K_{315})$	6.81^a	25.75^a	16.75^a	15.19^a
$T_3(k_{420})$	6.44^a	28.00^a	16.81^a	14.63^a
$T_4(k_{520})$	6.75^a	26.81^a	16.56^a	14.75^a
$T_5(K_{630})$	6.19^b	26.94^a	17.81^a	15.44^a
LSD	0.67	NS	NS	NS
Phosphorous				
$T_1(P_{140})$ [Control]	6.88^{ab}	33.06^a	20.88^a	18.25^a
T_2 (P_{210})	7.25^a	34.75^a	21.19^a	18.13^a
$T_3(P_{280})$	6.75^{ab}	34.63^a	21.75^a	19.69^a
$T_4(P_{350})$	6.75^{ab}	32.81^a	20.63^{ab}	18.19^a
$T_5(P_{420})$	6.50^b	29.94^a	19.00^b	16.19^b
LSD	0.63	2.43	1.78	1.58

Means in the same column with the same superscript are not significantly different (P>0.05). LSD= Least significant difference, K=Potassium fertilizer treatment and P=Phosphorous fertilizer treatments

Potassium fertilizer treatments had no significant effect ($p>0.05$) on growth parameters (Table I). The application of potassium above 520 kg/ha significantly($p<0.05$) affected the number of leaves by 11.8% compared with the control. Through literature search there is limited result on this finding, although potassium is required to promote vegetative growth and development by playing a major role in many physiological processes such as cell division and elongation [11], this study indicated that *Arctium lappa* requires relatively low potassium for optimum growth performance. This result is in contrast to the early study where the elevated application of potassium significantly($p<0.05$) increased the yield of these growth parameters in different cultivated species [12, 13].

Phosphorous fertilizer application on *Arctium lappa* L. followed a similar trend as K treatment. The application of different P fertilizer rates did not record any significant ($p>0.05$) improvement on growth parameters measured (Table I). Surprisingly, the higher application of P at 420 kg/ha significantly ($p<0.05$) depressed plant height, leaf length, and leaf width by 9.5%, 9 %and 11.3% respectively compared to the control. This is in contrast to early study of Nyoki and Patrick [14] and that of Nkaa, Nwokeocha [15] where significant ($p<0.05$) improvement in growth parameters of cowpea varieties was recorded due to phosphorus application. Although phosphorous is a critical element for plant growth and development especially in shoot and root tip where metabolism is high with rapid cell division [16] which improves enzyme activation and carbohydrate metabolism [17], it is plausible to conclude that *Arctium lappa* requires limited phosphorus application. Being a wild species, this plant might have adapted to the low utilization of mineral resources for optimum growth.

B. Effects of fertilizer treatments on yield parameters of Arctium lappa L

Potassium fertilizer had no significant difference (p>0.05) on total biomass, fresh root weight, fresh leaf weight, and root diameter at all treatment levels compared to the control (Table II). However, the application of potassium at 420Kg/ha demonstrated the highest response with a 15% on total biomass, 13.3% on fresh root weight, and a 32% on fresh leaf weight compared to the control. Thus, an indication of the optimum K requirement for these traits in this experiment. However, root length was significant (p<0.05) on K treatments. Application of K at 315kg/ha increased root length by 34.8%, whereas, a 13% reduction was recorded by the application of K at 630kg/ha compared to the control. The 34.8% increase at K_{315}Kg/ha could be attributed to the optimum K level as a major nutrient for root development [18]. This conforms with that of Khan and Sajid [19] who reported maximum root length for treatments with increased potassium [20].

TABLE II: INFLUENCE OF FERTILIZER TREATMENTS ON YIELD-RELATED PARAMETERS OF BURDOCK (ARCTIUM LAPPA L.) VALUES ARE MEANS AT (P-VALUES 0.05).

Treatments (kg/ha)	Total biomass (kg/ha)	Fresh root weight (kg/ha)	Fresh leaf weight (kg/ha)	Root length (cm)	Root diameter (cm)
Potassium					
$T_1(k_{210})$[control]	26775[a]	19550[a]	6825[a]	57.50[ab]	2.75[a]
$T_2(K_{315})$	21920[a]	14235[a]	7930[a]	77.50[a]	2.50[a]
$T_3(k_{420})$	30830[a]	22140[a]	9010[a]	64.00[ab]	2.75[a]
$T_4(k_{520})$	24270[a]	17545[a]	6360[a]	69.50[ab]	2.75[a]
$T_5(K_{630})$	27005[a]	19040[a]	7370[a]	50.00[b]	2.50[a]
LSD	NS	NS	NS	22.92	NS
Phosphorous					
$T_1(P_{140})$ [control]	28950[a]	21110[a]	8325[a]	54.25[b]	2.37[a]
T_2 (P_{210})	24435[a]	20718[a]	6795[a]	60.75[b]	2.75[a]
$T_3(P_{280})$	28740[a]	17500[a]	7823[a]	86.50[a]	2.75[a]
$T_4(P_{350})$	23590[a]	21068[a]	7178[a]	62.00[b]	2.25[a]
$T_5(P_{420})$	29220[a]	21068[a]	6198[a]	69.75[ab]	3.00[a]
LSD	NS	NS	NS	23.83	NS

Means in the same column with the same superscript are not significantly different (P>0.05). LSD= Least significant difference, K=Potassium fertilizer treatment and P=Phosphorous fertilizer treatments

Phosphorous fertilizer had a similar scenario to that of K treatments. However, the application of P at 420kg/ha demonstrated a slight 0.9% increase in total biomass compared to the control, demonstrating the highest response on total yield in this experiment. Fresh root weight and fresh leaf weight did not show any progressive increase from the control treatment. Thus, it is reasonable to say these parameters have a better response under low available soil P on *Arctium lappa* L. Nevertheless, Root length was significant (p<0.05) on P treatments. Application of P at 280kg/ha demonstrated the highest response with a 59.4% increase compared to the control.

C. Phytochemical screening of root and leaf extracts of Arctium lappa L.

Results on phytochemical screening for aqueous root and leaf extracts for P and K treatments were quite rich (Table III). Similar positive (+) and negative (-) test results were observed for aqueous root and leaf extracts, except for saponin that was present in the root but absent in leaf extracts. Even though, there is limited literature on this finding these results indicates that fertilizer treatments have less influence on the quality of phytochemicals on aqueous root and leaf extracts of *Arctium lappa* L. However, these results are in accordance with those of Al-Shammaa, Saour [21]who reported a positive (+) test for saponin, flavonoid, and tannin but a negative (-) test for Alkaloid on aqueous root and leaf extract of cultivated *Arctium lappa* L. collected from the Department of medicinal plants, College of Agriculture, University of Baghdad, Iraq. The presence of tannin in root and leaf complement the antiplasmodial activity of *Arctium lappa* L. [22]. Also, saponin for its anti-carcinogenic properties and other health-related benefits [23]. Furthermore, the presence of glycosides for the treatment of heart problems [24], complementing the therapeutic values of *Arctium lappa* L.

TABLE III: PHYTOCHEMICAL SCREENING OF AQUEOUS ROOT AND LEAF EXTRACTS OF ARCTIUM LAPPA L. IN RESPONSE TO TREATMENTS.

Root extracts	Tan	Sap	Flav	Terp	GLy	Alk	Phen	Ster
Phosphorous								
$T_1(P_{140})$[control]	++	+	++	-	+	-	+	-
$T_2(P_{210})$	++	++	++	-	+	-	+	-
$T_3(P_{280})$	++	++	++	-	+	-	+	-
$T_4(P_{350})$	++	+	++	-	+	-	+	-
$T_5(P_{420})$	++	+	++	-	+	-	+	-
Potassium								
$T_1(K_{210})$[control]	+	+	+	-	+	-	+	-
T_2 (k_{315})	+	++	+	-	+	-	+	-
$T_3(K_{420})$	+	++	+	-	+	-	+	-
$T_4(K_{520})$	+	+	+	-	+	-	+	-
$T_5(K_{630})$	+	+	+	-	+	-	+	-
Leaf Extract	**Tan**	**Sap**	**Flav**	**Terp**	**GLy**	**Alk**	**Phen**	**Ster**
Phosphorous								
$T_1(P_{140})$[control]	+	-	++	-	+	-	+-	-
$T_2(P_{210})$	+	-	++	-	+	-	+	-
$T_3(P_{280})$	+	-	+	-	+	-	+	-
$T_4(P_{350})$	+	-	+	-	+	-	+	-
$T_5(P_{420})$	+	-	+	-	+	-	+	-
Potassium								
$T_1(K_{210})$[control]	+	-	+	-	+	-	+	-
T_2 (k_{315})	+	-	+	-	+	-	+	-
$T_3(K_{420})$	+	-	+	-	+	-	+	-
$T_4(K_{520})$	+	-	+	-	+	-	+	-
$T_5(K_{630})$	+	-	+	-	+	-	+	-

Legend: (++): Highly present; (+): present; (-): Absent, Tan=Tannins, Sap= Saponins, Terp=Terpenoids, GLy= Glycosides, Alk= Alkaloids, Phen= Phenols and Ster= Steroids

D. Proximate analysis of root and leaf samples of Arctium lappa L

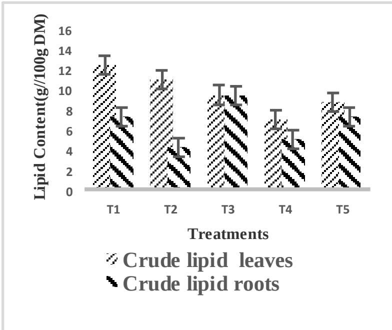

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Fig. 1a. Influence of Potassium fertilizer on Crude lipid content of burdock (*Arctium lappa* L.).

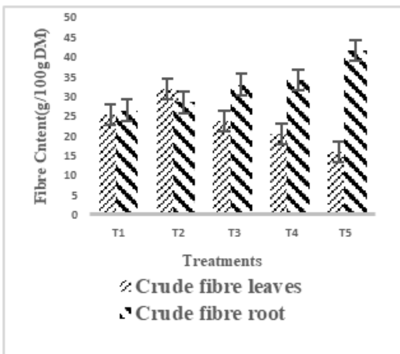

Fig. 1b. Influence of Potassium fertilizer on Crude fibre content of burdock (*Arctium lappa* L.).

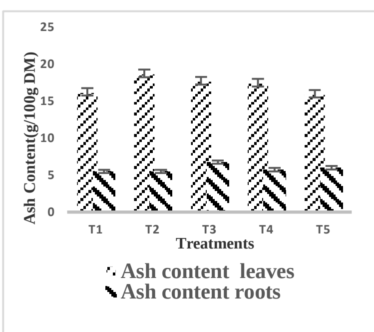

Fig. 1c. Influence of Potassium fertilizer on Ash content of burdock (*Arctium lappa* L.).

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Crude lipid and ash content for root and leaf samples were not significant ($p>0.05$) in response to K fertilizer (Fig.1a&c) However, crude fibre content was significant ($p<0.05$) to K treatments (Fig. 1b). Higher lipid content was obtained in leaf than root samples. Application of K at 210kg/ha recorded the highest crude lipid content (12.5%) in leaf whereas, in the root, the highest (9.5%) was recorded by the application of K at 420kg/ha with a 32% increase compared to the control. Ash content demonstrated the same scenario as crude lipid content. Application of K at 315kg/ha recorded the highest ash content (18.8%) in leaf whereas in root the highest (6.8%) was obtained by K at 420kg/ha. Nevertheless, the crude fibre content in leaf was significant ($p<0.05$) but not significant ($p>0.05$) in root in response to fertilizer treatments. Application of K at 315kg/ha recorded the highest crude fibre content (31.8%) with a 25% increase in leaf, whereas, in the root, the highest (41.8%) was obtained by K at 630kg/ha compared to the control.

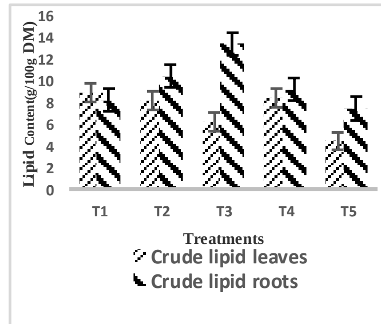

Fig. 2a. Influence of Phosphorous fertilizer on crude lipid content of burdock (*Arctium lappa* L).

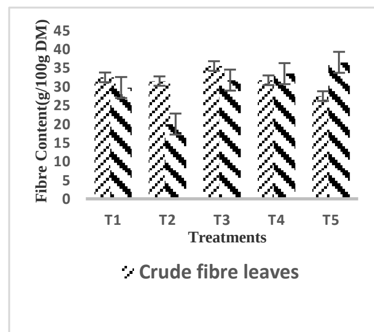

Fig. 2b. Influence of Phosphorous fertilizer on fibre content of burdock (*Arctium lappa* L).

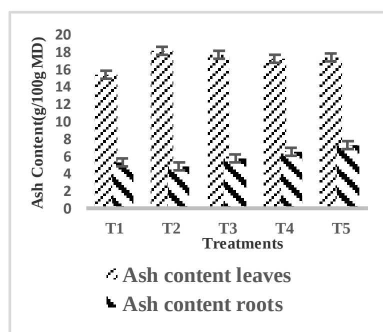

Fig. 2c. Influence of Phosphorous fertilizer on ash content of burdock (Arctium lappa L).

Phosphorus had no significant effect($P>0.05$) on crude lipid and ash content in root and leaf of *Arctium lappa* L (Fig.2a &b). However, Crude fibre content was significant ($p<0.05$) to P treatments (Fig. 2b). The application of P at 280kg/ha recorded the highest crude lipid content (13.5%) in root with a 63.6% increase compared to the control which was highest (9%) in the root. On the contrary, ash content was higher in leaf than root. The application of P at 210kg/ha recorded the highest ash content (18.3%) in leaf. Whereas, the application of P at 420kg/ha recorded the highest (7.3%) with a 38% increase compared to the control in the root. Also, the application of P at 420kg/ha recorded the highest fibre content (36.5%) in root with a 22.7% increase compared to the control. In leaf, the highest (35.5%) was recorded by the application of P at 280kg/ha with a 9.2% increase compared to the control. The dietary reference intake for lipids in adults is 20-35% of total calories from food. However, the highest crude lipid 13.5% in roots and 12.5% in leaves was recorded. According to [25], a moderate amount of lipid has health benefits in the body. The high crude fibre content in the root(41.8%) for K and 35.5% for P recorded in *Arctium lappa* L. suggests it can be a potential source of dietary fibre for anti-tumorigenic and hypocholestrolemic properties [26]. This implies it may be recommended for people with cholesterol-related problems [27]. The overall high ash content in leaves of *Arctium lappa* L. implies it can be a very nourishing and suitable vegetable for consumption.

IV. Conclusion And Recommendations

This study provided preliminary knowledge on nutrients requirements and cultural practices for the cultivation of *Arctium lappa* L in the wine land region of the Western Cape Province of South Africa. It provided an insight on the influence of fertilizer treatments on growth, yield, and phytochemicals of this species with regards to its therapeutic and nutritional values. The study revealed that this species requires a limited amount of potassium and phosphorous application for optimum growth and enhancement of phytochemicals and as a wild species it might have adapted to low utilization of mineral resources for optimum growth and development. However, more studies need to be done on fertilizer treatment combinations especially in the field to scientifically validate a possible protocol for the cultivation of this species. in South Africa.

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